UGUST, 1944 ONE SHILLING & SIXPENCE

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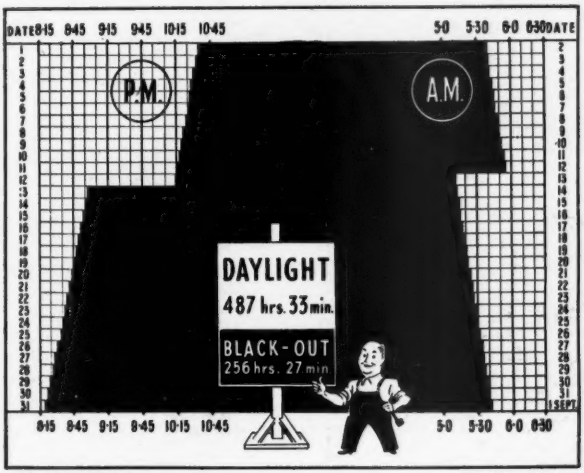

★*Times shown are those for the London area.*

Reproduced from the Nautical Almanac by permission of the Controller of H.M. Stationery Office

In August, the extra hour of daylight is lost to the industrial war effort, and besides, black-out hours increase alarmingly with the shortening days. Preparations are being made for winter-lighting schemes adjusted to assist a still greater output, and Osram will continue to be the choice of all who demand of their lamps really dependable service under all conditions.

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THOMAS DE LA RUE & COMPANY

Expansion in Every Sphere of Activity

Future of Plastics

The 47th Ordinary General Meeting of Thomas De La Rue & Company, Limited, was held in London on 2nd August.

The following are extracts from the statement by Mr. B. C. Westall (chairman and managing director), circulated with the accounts:—

I am very glad to be able to report continued expansion in every sphere of the Company's activities.

The major part of the total profits (£311,629) derive from the parent company's manufacturing activities, which are now confined to Security Printing. The process of re-equipment of plant destroyed at the end of 1940 has continued and the additional machinery brought into operation during the year has enabled us to undertake an increased volume of business. Furthermore, the plant is dispersed in three different areas so that any complete stoppage, such as was brought about in the early part of the war, is most unlikely to recur. The volume of business in hand compares favourably with that of a year ago, and the prospects for the year ending March, 1945, are encouraging.

THE MORE DISTANT FUTURE

With regard to the more distant future, it does not seem unreasonable to hope that many countries of the world will look to Great Britain for their bank and currency notes and we do not anticipate that we shall fail to get a fair share of such business.

The policy of transferring the Plastics and Stationery business to separate subsidiary companies has been fully justified.

De La Rue Stationers Limited, under the experienced guidance of the Managing Director, Mr. W. F. Wardley, has had, in spite of the difficulties of the times, a very satisfactory year. New premises at Imperial House, Regent Street, have been engaged as the headquarters of that Company with sufficient accommodation to provide for the expansion of business which we may expect when the war is over. Until then, shortage of materials will continue to restrict its activities.

ONOTO PEN SERVICE

We have received many letters from members of the Forces praising the manner in which the Onoto pen has stood up successfully to very severe conditions in many parts of the world. Such tributes are encouraging signs for the future of our pen business when restrictions are removed.

It has been a source of regret to us that we have not been able to supply the Trade with a greater quantity of our playing cards.

NEW PLASTICS COMPANY

The process of reorganisation and consolidation of our subsidiary, De La Rue Plastics Limited, has been continued. The Directors found it desirable to form a separate company, Scottish Plastics Limited, for the operation of the Scottish factory and business. This new company, which is a subsidiary of De La Rue Plastics Limited, will continue to manufacture the Onoto pens for De La Rue Stationers Limited. Its main objective, however, will be the development of Plastics in Scotland.

The Directors of De La Rue Plastics Limited have purchased Hammans Industries Limited, together with its associated concerns, and combining these with the Laminated Section they have formed a composite company named De La Rue Insulation Limited, of which Mr. J. Eerdmans has been appointed Managing Director. The growth in this section of our plastics business has been very rapid and this form of plastics manufacture is likely to have very considerable application in peace time. This material has definite advantages over wood and as timber is likely to be in short supply for a considerable time, steady expansion of the new company may be expected.

HIGH LEVEL OF OUTPUT

The output of De La Rue Plastics Limited, under the energetic drive of the Managing Director, Mr. H. P. Bridge, has continued at a high level. A very high percentage of the work has been for the Fighting Services. While a certain amount of dislocation is bound to occur in the change-over from war-time to peace-time production, we are fortunate in that a considerable number of moulds is available for immediate use.

RESEARCH AND DEVELOPMENT

The policy of enlarging the Research and Development Departments has been continued. During the war our activities have been restricted to finding new applications of plastics to war purposes. Even more could have been done had we been able to obtain sufficient technical staff with the necessary qualifications for carrying out research. It is to be hoped that the Government will bear in mind the desirability of making available for industrial concerns at the earliest moment possible experts in chemistry and engineering, so that the groundwork for industrial expansion may be prepared in good time. In a comparatively new industry such as plastics, research and development are even more important than in the case of the older-established industries. In our own case, the Board of De La Rue Plastics have many projects in view which must await the engagement of technicians.

NEED FOR RELAXATION OF CONTROLS

Speaking generally, the future expansion of our Plastics business will depend upon the speedy relaxation of the system of controls. All Industrialists have realised the necessity for a strict control of raw materials in war-time, and in my view the Controls have functioned fairly and efficiently. Nevertheless, it is patent that a condition of affairs is unhealthy when one manufacturer is unable to acquire new plant because some other manufacturer has plant that is partially idle. Such procedure tends to subsidise inefficiency. It is to be hoped that the system of purchase of plant by licence may be speedily abolished. Until then I trust that Controllers may be directed not to withhold such licences in cases where it can be shown that no interference would be caused to the production of munitions.

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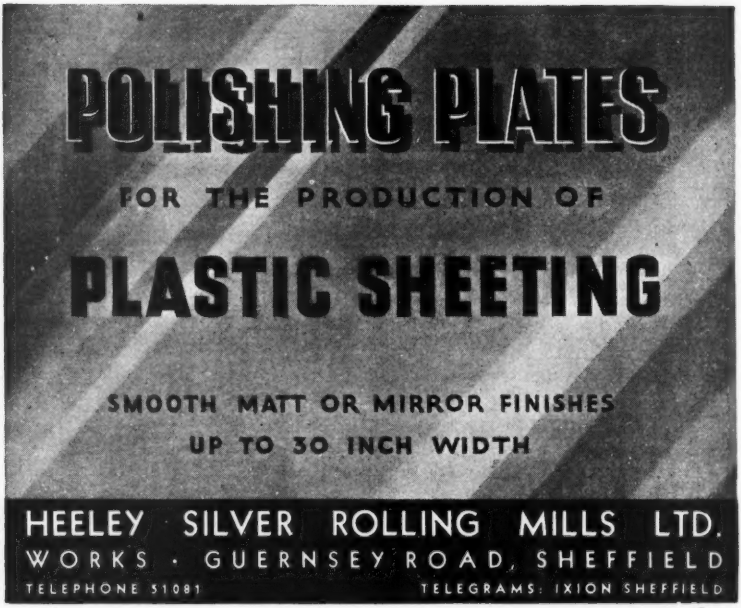
Alice in the Elo Research Laboratories

Rows and Rows of bottles. Regiments of Test Tubes . . . a glimpse of the alchemy at the back of plastics. Alice stood and gazed into the Elo Laboratory. "What a lot there is behind the prosaic word plastics," thought Alice. What a long road there is to travel from the laboratories to the finished product reposing comfortably in a showcase. What interest there is in plastics when one takes the trouble to explore. "Still I built my reputation on curiosity" thought Alice, "and even in modern times I look like keeping it." Anyhow we'd better have a close-up of this section" said Alice, and wandered meditatively into the laboratory.

ELO

PLASTICS

Full reliable information and data from
Research Section, BIRKBYS, Ltd., Liversedge, Yorkshire.



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b With our wide experience in printing and engraving we set about developing the fabrication and manipulation of all these plastic materials. The introduction of these new materials and the exacting requirements of the war quickly brought us to the point where we were able to manipulate and fabricate plastics of all kinds, in sheet, rod and tube.

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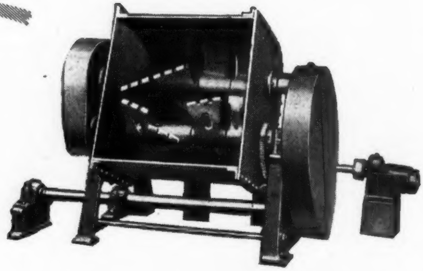

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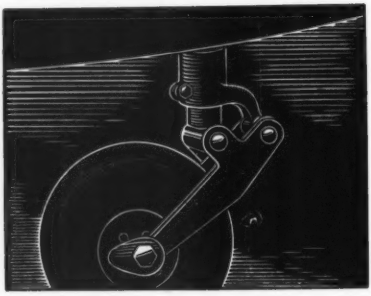

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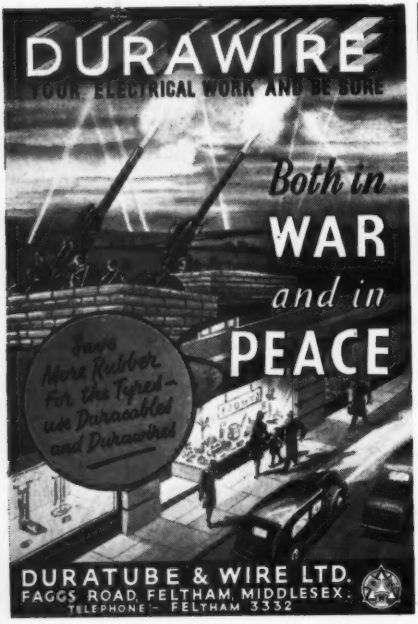

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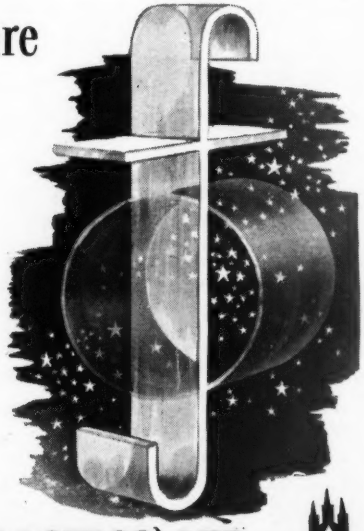

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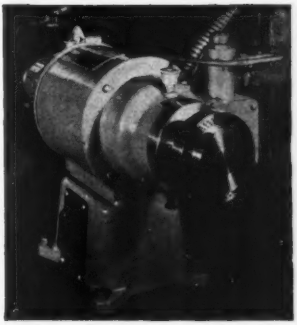

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TREFOIL

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Pioneers in the Plastics World

T17

BAKELITE LIMITED, 18 GROSVENOR GARDENS, LONDON, S.W.1

Vol. VIII. No. 87 AUGUST, 1944

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - - TEMPLE PRESS LIMITED
Managing Director - ROLAND E. DANGERFIELD

Editor - - M. D. CURWEN, B.Sc., A.R.I.C.
Offices - Bowling Green Lane, London, E.C.1

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NOTICES

All instructions, matter and passed proofs for all kinds of advertisements must reach the Head Office of "PLASTICS" by the 24th of each month to ensure insertion in the following month's issue.

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The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Plastics and Insecticides

IT has always been our belief that if you work hard enough on a material chemically and physically, you will find out something new about it. We have also reiterated ad nauseam and to the disgust of many of our readers that there is not enough industrial research done in this country.

Our interest in this direction has suddenly been awakened by the announcement that the Dow Chemical Co. of Midland, Michigan, is producing styrene dibromide in bulk and that it is used as an ingredient in a specially formulated corn worm control. It is a solid insoluble in water, soluble in organic solvents, and has a melting point of 71 deg. Centigrade.

Now styrene dibromide may or may not be an entirely new material—we haven't taken the trouble to look up our Beilstein—and normally almost one of the first things an organic chemist does to an unsaturated compound like styrene is to treat it with chlorine, bromine or iodine so that it is likely that styrene dibromide was first made a long time ago—and forgotten. The compound cannot be polymerized into a plastic and should not be confused with polybromstyrene.

The interesting bit about its appearance on the market is the fact that Dow's, who make styrene and a very fine polystyrene for the plastics industry from it, has the kind of mind that looks round corners and the inquisitiveness and ability that can apply one bit of information to new uses.

It may seem curious that styrene dibromide should even be thought of as being useful as an insecticide. It may be the result of accident or past experience. The main thing to realize is that in the U.S.A. and also in Germany there is an attitude of mind among scientists lacking in this country. The science-to-industry link is comparatively weak.

Generally speaking, a manufacturing company in this country devoted to plastics is not interested in producing anything else but plastics, perhaps on the assumption that it is only possible to do one thing well. There is a fallacy in this argument we are sure. The trouble is that there are very few scientists here who know much about what is required in industries with which they are not directly connected and have little desire to acquire that knowledge.

Styrene dibromide, which we take only as an example, may be a strange material for a plastics concern to handle, but apparently there's money in it. If it turned out to be a good fire extinguisher or a medicinal soporific, as well it might, we still think it is up to the plastics concern to do the research and to develop it industrially, although not necessarily through its own immediate organization. The plastics concern should know everything about their raw materials, whether they result in plastics or not; not only for the sake of science but for the sake of industry, which means the welfare of the country.

Hygienic Plastics

FOR many years past there have been attempts, most laudable in their objective, to obtain plastic films, sheets and moulded objects which could reasonably be considered as bactericidal and fungicidal. It is well known that paint manufacturers have long made this attempt, and, it is claimed, with fair success. The object is, of course, to provide hospitals primarily, and houses and factories generally, with surface walls that accord with the highest principles of hygiene.

Where plastics and the sheet variety, laminated or otherwise, possess a preliminary advantage, is their smoothness of surface on which dirt clings less

strongly than non-polished surfaces and the ease with which such surfaces can be kept clean.

In the early days of the industry it was claimed that the presence of phenol and cresol imparted a high bactericidal value to sheets and moulding. While there is a stratum of truth in this, excess phenol could indicate a poor moulding and besides, phenol is not only somewhat volatile, but has a very low bactericidal value compared with modern germicides. More recent additions to obtain better effects included the higher phenols, thymol, chlor-thymol, and the like.

The news that dichlor-diphenyl-trichloroethane has been rediscovered to be a remarkable insecticide will no doubt cause certain plastic and paint manufacturers to include this compound in their mixes in addition to bactericides.

Dichlor-diphenyl-trichloroethane is a white, sweet-smelling powder, which is death to any insect. It is also entirely harmless to man, so it is claimed, although, from its chemical composition, we should have thought that it was rather toxic. It is amazingly so to the mosquito, to typhus-bearing lice and other insects, the substance having been found invaluable to our troops in Italy and the Pacific. An epidemic of typhus in Naples was put out "like a light."

It is to be hoped that mixed with plastics or plastic films it would still retain its lethal properties.

University Research Fellowships

Announcement by the Directors of Imperial Chemical Industries

The directors of I.C.I. have offered to provide at nine universities in Great Britain Fellowships to be held by senior workers in certain sciences. The scheme is announced to operate for an initial period of seven years. The Fellowships will be of the average value of £600 per annum, though the universities will have power to determine the emolument for each particular appointment. The directors of I.C.I. have described on broad lines the subjects in which the Fellowships are to be held and the administration of the scheme rests wholly with the universities, which will select and appoint the Fellows, subject only to such conditions as to duties and tenure as the universities themselves impose.

The purpose of the directors in instituting this scheme is to strengthen the general provision in the British universities for scientific teaching and research. The directors believe that academic and industrial research are interdependent and complementary, and that substantial advances in industry cannot be looked for without corresponding advances in academic science.

In their view, it is important that the immediate objective should be the strengthening of university scientific departments in whatever way each university thinks to be best. No conditions whatever are attached by the directors to the tenure of these Fellowships. The Fellows will be members of the university staffs and will be concerned only with the duties laid upon them by the universities. Their primary work will lie in research. But they must also take some part in university teaching. It is intended not to relieve the universities from the cost of maintaining any part of their normal work, but to enable them to add to what they already do.

The universities to which this offer has been made comprise the larger metropolitan universities, and those which have a close geographical relation to the main centres of the company's production. Twelve Fellowships have been offered to the Universities of Oxford, Cambridge and London, eight to the Universities of Glasgow, Edinburgh, Manchester, Birmingham and Liverpool, and four to the University of Durham.

The directors believe that a rational policy of this character, together with a wise selection of men, both as regards capabilities and tenure of office, will lead to the emergence of a body of men capable of taking high academic or industrial positions, thereby advancing academic and industrial research.

NEW BOOK

Varnish Constituents, by H. W. Chatfield, Ph.D., B.Sc., F.R.I.C. Published by Leonard Hill, Ltd. Pp. 496. Price 35s. net.

We suppose it is within the memory of hundreds of workers in the paint industry when each and every component in varnish and in paints came from natural sources. What a revolution has come over this complicated and now scientifically controlled industry! While linseed oil still rules the roost, and tung oil (when it can be obtained) is still without compare for special jobs, synthetic resins have laid a deep impress on

modern production, plasticizers have appeared in their hundreds and new driers and diluents, very different from the old type of inorganic compounds and the staple turpentine, are now being widely used. Even synthetic drying oils are being carefully examined by the industry. Chemicals which impart special effects are legion.

With this deluge of new materials and its continued increase it is high time that their systematic examination and correlation were placed in book form.

Dr. Whitfield, who is departmental manager to Messrs. Jenson and Nicholson, Ltd., the famous paint and varnish manufacturers, has carried out this work in a manner that deserves the especial thanks of the varnish-making industry. If we apply the somewhat overworked word " unique " to this book, it is because we have not hitherto encountered so technical a volume that is at once simple and pleasing to read and yet appears to our mind to cover all the modern developments in this sphere.

The plastics industry, too, will be grateful to Dr. Whitfield, not only because the varnish industry has become one of its most important customers, but also because of the wealth of information contained in the book on the production of phenolic resins, modified and unmodified, and their incorporation into oil, of maleic resins, coumarone, urea-formaldehyde, melamine, polystyrene, polyvinyl and polyvinal acetal, polyacrylic and polymethacrylic resins, their application and special uses.

A special section of the plastics industry, namely, that engaged in sheet and film production, will find in the author's careful and detailed exposition of the use and effect of plasticizers and modifying agents, such as the chlorinated diphenyes, synthetic waxes and so on, of great help in their work.

This is an invaluable book.

London and Fly-bombs!

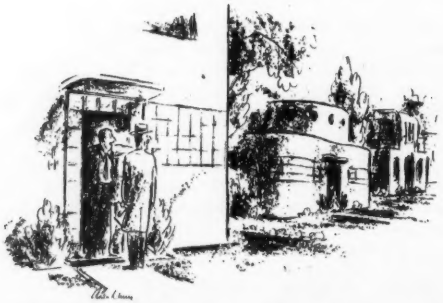
(Tribute from " The Manchester Guardian ")

" A fly may sting a horse and make him wince, but one is an insect and the other still a noble animal.—(Anon.)"

The following is another note from " The Manchester Guardian " which we hope will be appreciated by every Briton:—

" For us Anglo-French friendship is a matter of life and death, both material and spiritual: Western Europe can know no security and Western civilization cannot flourish without a deep and lasting partnership between England and France. And there is something more. Of all the countries now fighting Germany, only England and France did not wait to be attacked, but entered the war voluntarily for the freedom of others. War will lose its meaning unless at the end the representatives of England and France stand side by side as equals."

LET US LAUGH AT OURSELVES



" After the second house beyond the polystyrene you'll come to a two-storey phenol-formaldehyde—that's it."

(With acknowledgments to the F.M. Dodge Corporation " Record," U.S.A.)

Synthetic Resins in the Surface-coating Industry

By C. I. PHILLIPS, B.Sc., A.R.I.C.
(Berger Plastics Development, Ltd.)

IT is perhaps not generally realized by those engaged in the plastics moulding industry that the discovery of new resins primarily intended for the production of moulded articles has, within the last few years, greatly influenced the direction of progress in the surface coating industry.[1]

Paint binders or vehicles have been continually modified as our knowledge has increased about the way in which the film protects the material to which it is applied, and the latest discoveries in other fields have been applied to improving this film and its efficiency of protection. Of all the industries which have been " co-opted " by the paint trade, none has had such influence as the plastics industry.

In order to see how this has come about it is necessary to consider briefly the trend of vehicle development in paint technology in the past.

The early vehicles were simply solutions of raw or treated drying oil in a solvent, such as turpentine. They gave films of fair gloss and durability but of poor water resistance and very slow rate of drying.

Early Natural Resins

The first advance was the introduction into the oil of various oil-soluble natural resins, such as colophony or copal, which resulted in greatly improved gloss and drying time proportional to the resin content.

Most work, until very recent times, was concerned with the evolution of new resins which were soluble in such drying oils as linseed oil and also soluble in the inexpensive solvents used by the paint trade. Such resins were used in varnishes always in conjunction with a relatively large amount of drying oil.

A new stage in the evolution of the varnish was reached when oil-soluble synthetic resins were placed on the market. One of the first was the type evolved by Albert and Behrend,[2] who first formed the phenol-formaldehyde resin in the normal manner, and then " modified " them by heating with oil-soluble natural resins. Hard resins were formed of good oil solubility, but of limited durability and of poor colour retention.

First Synthetic Resins

By resinifying specially selected phenols with formaldehyde, synthetic resins were produced which were oil-soluble without any special modifying treatment. Such phenols[3] were of the para substituted type, for example, p. tertiary butyl phenol. It is to be noted that the amount of yellowing in sunlight undergone by such resins was very much less than the modified resins, probably because the use of the para substituted phenols prevents the formation of para quinonoid complexes which could act as chromophore groups in the production of colour.

The resins which up to the moment have found their greatest use in the paint trade are the alkyd resins. Since their commercial introduction in the decade after the last war, the use of such resins for varnish making has grown enormously, and the quantity of alkyds now made for the paint trade exceeds the quantity of phenol-formaldehyde and urea-formaldehyde resins made for the moulding industry.

These alkyd resins are produced by the condensation of polyhydric alcohols with polybasic acids. Thus, when equivalent weights of phthallic anhydride and glycerol are heated together, water is eliminated and a fusible resin is first produced. If the heating is continued gelation occurs at a stage corresponding to 80 per cent. esterification.

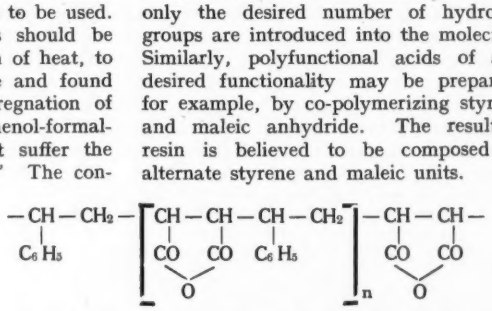
If the reaction is stopped before gelation occurs, a brittle resin is formed soluble in acetone. Such solutions in acetone were the first alkyds to be used. Films from these varnishes should be stoved off by the application of heat, to the insoluble, infusible state and found their main use in the impregnation of electrical coils, as, unlike phenol-formaldehyde resins, they do not suffer the disadvantage of "tracking." The conversion of the fusible film to the infusible state is accomplished by heat and is a relatively slow process.

The majority of alkyd resins now used in the paint industry are the oil modified type. These are produced by several methods, of which the principle is to substitute part of the poly-basic acid with a vegetable oil acid, particularly one derived from a drying oil, such as linseed. Resins produced by this method give films which will further polymerize in the air at room temperature by the oxygen induced by polymerization of the unsaturated radicals.

Trend of Research

The trend of alkyd research resolved itself into a search for resins which could be converted more rapidly than the already existing types and which would give tougher films of enhanced durability. Thus, from the preparation of resins from glycerol and pthallic anhydride, interest turned to other polyfunctional acids and alcohols. The use of the tetra functional base pentaerythritol, containing four primary hydroxyl groups of very considerable reactivity, enabled resins to be prepared in a shorter time which stoved in a greater degree of cross linking in the converted form. Polyfunctional acids, such as citric acid, were also used.

With the introduction of polyvinyl alcohol, another polyfunctional alcohol was added to the list. The reactivity of this material can be adjusted to practically any desired value either by the complete hydrolysis of suitably selected molecular weight polyvinyl acetate or by the hydrolysis of the latter under controlled conditions of alkalinity so that only the desired number of hydroxyl groups are introduced into the molecule. Similarly, polyfunctional acids of any desired functionality may be prepared, for example, by co-polymerizing styrene and maleic anhydride. The resulting resin is believed to be composed of alternate styrene and maleic units.



It is only within comparatively recent times that research has been directed to the formation of surface coatings almost entirely composed of synthetic resins which do not have to be incorporated with vegetable oils to obtain flexibility and durability. In such cases the film is produced by an entirely different process. Instead of the solvent evaporating off to leave a more or less liquid film which requires oxygen to enable it to slowly convert to the solid form, as was the case with previous film formers, the film is deposited in its final hard state immediately the solvent evaporates.

The first of these new materials were the nitrocellulose lacquers. These yielded films of great hardness and extreme speed of drying, but which suffered, however, from poor gloss and necessitated the use of expensive and odorous solvents.

Much work has now been carried out to perfect other synthetic resins of this type which require no further chemical processes to attain their full hardness. It has long been realized that the newer

thermoplastic resins offer many attractions to justify their use in surface coatings,[4] such as their paleness of colour and their very excellent non-yellowing properties, and their high degree of chemical resistance. However, if the resin is suitably plasticized and formulated into a varnish it is found that, on exposure, crazing soon develops and the film rapidly breaks down. Such resins, however, find application in rather specialized coatings, such as " stopoff " lacquers in electrochemical plating, where varnish is applied to that part which requires no depositions.

Another disadvantage of varnishes made from these resins is their very high viscosity at low solid concentrations owing to their high mean molecular weight. It has, however, been found possible to use the newer thermoplastic resins either by the chemical modification of the parent monomer, or by co-polymerizing it with substances which confer advantages on the resulting resin and makes it satisfactory for use in the paint trade. In general, such modifications are designed to give low mean molecular weight in order that the viscosity should not be too high and should confer solubility in the cheaper solvents.

Thus the viscosity of rubber solutions are very high, and films produced from them have poor durability owing to oxidation at the double bonds present. However, if the rubber is chlorinated the solubility of the resultant product is improved and the films are of greater flexibility and durability owing to the lessened unsaturation of the rubber molecule, which corresponds to lessened chemical reactivity.

Polyacrylate Resins

The polyacrylates have also been utilized for the newer surface coatings. Whilst polymethyl methacrylate is unsuitable, due to its brittleness and high viscosity in solution, polybutyl methacrylate was found to be much more suitable as a surface coating medium, being soluble in inexpensive solvents and producing films of greater flexibility. The usual preparation of butyl methacrylate is from methyl methacrylate by a process of ester interchange. The methyl methacrylate is heated with butyl alcohol in the presence of sodium methoxide as catalyst.[5] Methyl alcohol is then distilled off.

$$CH_2 : C.(CH_3)\,COO\,CH_3 + Bu\,OH \rightarrow CH_2 : C.(CH_3)\,COO\,Bu + CH_3\,OH$$

It can be readily seen that instead of butyl alcohol one of the higher alcohols, such as oleyl alcohol, can be incorporated, and by this means an " internally " plasticized resin is obtained which possesses the advantage over the simple addition of plasticizer in that the evaporation of the latter is prevented and better stability and durability of the system is gained.

Polystyrene Resins

Polystyrene resins have also been utilized for the production of surface coatings, but so far only to a limited extent. Polystyrene of molecular weight 30,000-40,000 will form varnishes of very excellent chemical resistance, and which are very light stable, but the films are brittle and of poor durability, and as solutions are highly viscous. Low molecular weight grades produced by the introduction of a light stable phenol into the reaction mixture produced more suitable lacquer components.

It is interesting to note in this connection that drying oils are finding new and interesting applications as modifying ingredients. Thus, both methylacrylate and styrene have been copolymerized with a small proportion of certain drying oils[6] to produce interpolymers which, amongst other applications, are suitable for the formation of varnishes. Such oil-modified polymers are usually of much lower molecular weight, since the oil appears to combine with the growing polymer chains, and thus to curtail the chain lengths. Solutions of such resins are hence much less viscous and the films more flexible. As used in copolymerization techniques, drying oils would appear

to confer interesting possibilities of obtaining cross-linked polymers of the styrene divinyl-benzene type.

New Resins and New Techniques

Nylon has been a recent addition to the list of synthetic resins. Its use so far in varnishes has been largely limited to coating wires from a solution of the resin in hot phenol or formamide. It is obvious, however, from the published literature that vigorous attempts are being made to extend the use of this very valuable thermoplastic material and the principle upon which it is based.

Some use has also been made[1] of the cold-hardening phenol-formaldehyde and urea-formaldehyde syrups. The advantage of such varnishes is that the resulting film, although it has not been stoved, has all the properties of the thermo-hardened film as regards chemical stability and water resistance. They can thus be used wherever it is impracticable to convert the resin by heat, such as on sensitive veneers.

More use is now being made of the processes for coating articles with a resin film by means of various types of heat guns. The principle is to conduct a fine stream of powdered thermoplastic resins through a zone heated in some manner (usually by gas or electricity) so that the resin is softened. The blast of softened resin is now directed on the article to be coated and a coherent adhesive film is produced which requires no further treatment and can be handled immediately. With some resins a certain amount of depolymerization occurs, and the temperature of the heated zone must be held to close tolerances, which vary for different resins.

As has already been explained, all former varnishes contain the film-forming material dissolved in a solvent which is finally completely lost and which contributes no part to the final film. It would seem that future work must include the aim of dissolving the resin in a solvent which will itself polymerize at room temperature and would therefore form part of the final film. A considerable saving in cost would result, and the obnoxious smell of many solvents might also be eliminated. Some work on this problem has already been done, using Thiokol and allyl maleate. Thiokol, which is ethylene polysulphide, is made by reacting ethylene chloride with sodium polysulphide with the elimination of sodium chloride.

$$Cl\,CH_2\,CH_2\,Cl + Na_2\,S_4 \longrightarrow -CH_2-CH_2-S(=S)-S(=S)-CH_2-CH_2- + 2\,NaCl$$

It has now been established that if the resin is dispersed in allyl maleate, a reaction occurs between the double bonds of the allyl group and the sulphur linkages with the production of a new solid resin, which is insoluble and infusible and hence cross-linked. It is reasonable to suppose that other combinations of resin and polymerizable solvent will be evolved and should hasten the new solventless era in surface coatings.

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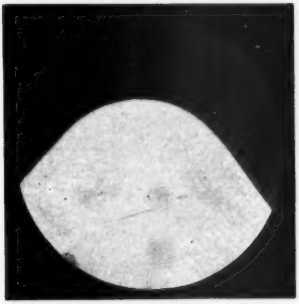
Waterproof Covers for Firearms

An interesting application of polyvinyl chloride-acetate co-polymer sheet is described in the June, 1944, issue of "Modern Packaging." In order to provide a completely waterproof casing for the rifles of assault troops landing through seas and rivers, the arms are entirely encased in a very loose sheathing of the material suitably heat-sealed. There is sufficient air enclosed to enable the weapon to float if dropped in the water and the covering is thin enough to enable the soldier to fire the rifle without removal of the casing. The film is Lumarith V.N., made by the Celanese Celluloid Corporation.

Diamond Tools for Plastics

Discusses the General Merits of Diamond as a Cutting Medium, Especially for High Precision Work;—



—Notes its Limitations and Outlines its Special Application in the Plastics Field

Fig. 1.—Photomicrograph of diamond tool edge for the turning of plastic materials. (Magnification 100 reduced to ½.)

PLASTICS and allied non-metallic materials have found so extensive an application in every phase of modern industry that it is difficult to give a complete review of all the possibilities of machining them with diamond tools.

Plastics are probably best known in the form of mouldings, and here it is, in general, sound economics for the designer to create an article which is completely finished when it leaves the mould, which, as is usually the case, is highly polished, and will confer on the moulding a correspondingly high degree of finish. Sometimes, however, machining operations, such as sawing and milling (for instance, in the case of combs) cannot be avoided. Again, whenever an exact geometrical form or a mathematically correct surface is required, machining must frequently be resorted to.

It may at first seem strange that the hardest of all known tool materials, the diamond, should be necessary for the finish-turning of comparatively soft materials such as the phenolic resins, hard rubbers and similar materials. It is, however, quite well known that even the finest lathe tool of present-day high-quality steel is not capable of turning a single billiard ball without regrinding. A diamond tool is capable, on the contrary, of finish-turning three thousand or more billiard balls all perfect as regards shape and finish before relapping is required.

Plastics themselves possess certain intrinsic abrasive properties; the filling materials used in conjunction with them, such as talc, chalk, asbestos, silica flour and textiles, have an even more pronounced effect and, to a greater or less extent, soon cause deterioration in the cutting edge of steel, hard metal or ceramic tools. Thus, the diamond tool, in spite of its high prime cost, will often prove ultimately more economical than tools constructed in a cheaper material. It should be pointed out, incidentally, that for certain plastic materials it is sufficient and, indeed, even advisable to employ tungsten-carbide tools if these latter be of complicated form; the expense entailed in the production of a profiled diamond cutting edge is, at the present moment, rarely justified.

Comparing the relative merits of hard metals and diamond tools, the temperature developed during the machining of insulating materials (which are mostly bad conductors of heat) is of importance. The diamond itself has a heat conductivity similar to that of certain of the

hard metals, but its hardness falls off even less at high temperatures than that of the carbides. The dense structure of the diamond makes it possible to grind an

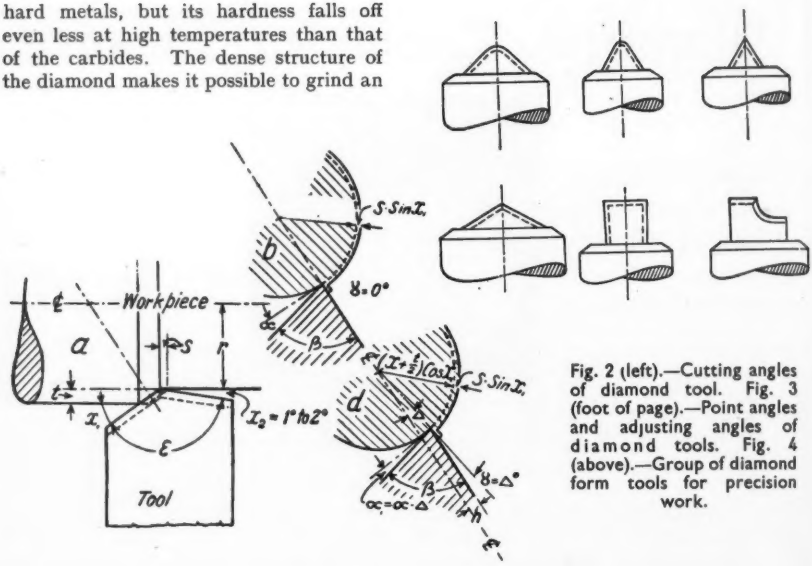


Fig. 2 (left).—Cutting angles of diamond tool. Fig. 3 (foot of page).—Point angles and adjusting angles of diamond tools. Fig. 4 (above).—Group of diamond form tools for precision work.

exceedingly sharp edge, superior in this regard to that obtained with sintered hard metals; such an edge is very desirable when machining plastics; cutting pressures and temperatures are both reduced as a result.

The high wear resistance of the diamond cutting edge, its high surface finish, sharpness and chemical inertness are also conducive to freedom of cutting with minimum pressure and friction at very high speeds—factors of importance when machining resilient materials of a rubber-like nature. Other tool materials require high pressures, and surface deformation is likely to occur when turning. The low cutting pressure required for diamond tools explains also to some extent the fact that they are little influenced by slots, grooves or other interruptions at the surface of the workpiece. It may be said, in fact, that where great quantities of parts are to be produced without frequent attention to cutting tools, then the diamond is preferable to most other materials.

For the machining of non-metallic materials, diamond tips may be produced in grades of diamonds requiring less critical selection than in the case of diamond tips for machining metal. The machining of hard rubber with diamonds became a general practice as long ago as 1860. It is interesting to note that when

attempts were made to employ these stones for machining metal it was at first thought that the same random choice could be made of suitable grades as proved satisfactory with non-metals. The results, however, were most disappointing; because of bad orientation with regard to cleavage planes, edges broke and work was spoilt. Only when "structure-cut" diamond tools were introduced was the problem solved in the case of metals.

These remarks indicate that for the machining of plastics diamonds of a somewhat lower quality can be usefully employed, the implication being that good all-round results can be obtained with comparatively low-priced tools. When ordering tools for the purpose, however, it is very important to specify exactly the material being worked and the conditions under which it is to be cut, i.e., cutting speed, cutting depth, and so on.

For the production of geometrically correct surfaces it is essential that only one cutting edge be in operation at a time. The clearance angle is usually between 5-10 degrees for turning tools. For the boring of plastic materials to very exact dimensions with diamond tools the clearance angle must be specially adapted on account of the relationship between the thickness of the diamond and the diameter of the bore. The optimum point angle for diamond tools is 120 degrees for straight surfaces and 170 degrees for multiple-facet tools; the width of a facet being from 0.004-0.040 ins. Tools for shoulder turning and special profiles, especially thread cutting tools, require point angles of less than 90 degrees, but owing to the weakening of the cutting edge and the probable effect on surface finish, the use of these tools should be confined only to cases where it is virtually indispensable.

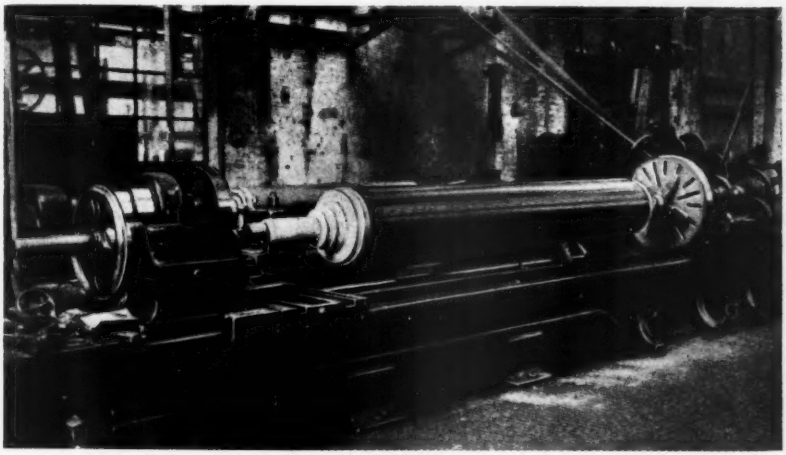


Fig. 5.—Calender roller set up in special centre lathe for trueing of surface by diamond turning.

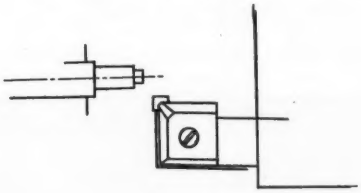
The optimum rake angle for diamond tools is from 0-3 degrees. A rake of 0 degree eases the problem of tool production and the checking of the tool in relationship to the workpiece. In general, it is advisable to adjust the tool slightly above the centre height of the workpiece. The front adjusting angle is 45 degrees for diamond tools with one cutting edge and 18-30 degrees for multiple-facet tools. The rear adjusting angle, which should be as small as

possible, is best chosen from 1-2 degrees.

The first consideration regarding cutting speed for diamond tools is absolute freedom from vibration. Although the demands on machine tools engaged on work in plastics are not as exacting as in the case of diamond turning for metals, the machine, nevertheless, should be on a firm foundation; drive should be by means of endless belt and bearings should be in perfect condition and show no end play. All rotating parts should be perfectly balanced. Cutting speeds recommended for non-metallic materials vary according to current practice from 100-4,000 ft./min. (Table 1). Design and condition of machinery will exert some effect on optimum cutting speeds in individual cases. Feed and depth of cut depend on the shape of the diamond tool edge. Comparatively substantial chips can be removed with a diamond tool when cutting plastics, but in order to obtain a good surface finish the feed must not be more than a fraction of the length of the cutting edge. Small feeds and light cuts produce high surface finish and enable very high cutting speeds to be maintained. Feeds of 0.0012-0.424 in. per rev. (the latter feed for large calender rollers) are frequently applied with cutting depths of 0.004-0.048 in.

From Table 1 it will be seen that, in many instances, an infinite number of parts may be produced from a diamond tool before retouching of the edge becomes necessary; the finish throughout the whole cycle being such that no subsequent improving is required. The number of pieces per hour depends, of course, on size of the job, speed and feed.

Data given in Table 1 show the economy of employing diamond machining as a finishing process. The table contains only a short list of non-metallic materials which may economically be machined with diamonds; there are, however, many other substances suitable for machining with shaped diamond tools.



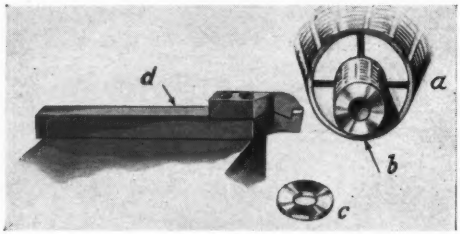
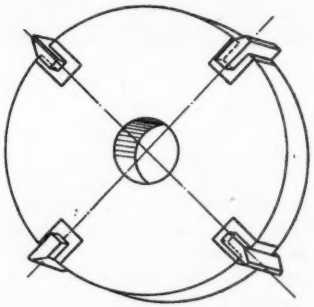


Fig. 6 (left).—Diamond parting tool used in production of hard rubber discs. Fig. 7 (above).—Diamond trapping tool for the turning of vulcanite mouthpieces for briar pipes. Fig. 8 (below).—Milling cutter for plastic materials with four inserted diamond edges.



It has been mentioned already that the diamond tool is particularly suitable for cutting resilient materials, such as rubber, on account of the comparatively low cutting pressure required as compared with that required for other cutting

materials. As a result, the workpiece suffers no deformation during turning. Typewriter rollers, for example, are quickly reconditioned by skimming with diamond tools. The grinding process formerly used for finishing these rollers has largely been superseded by diamond

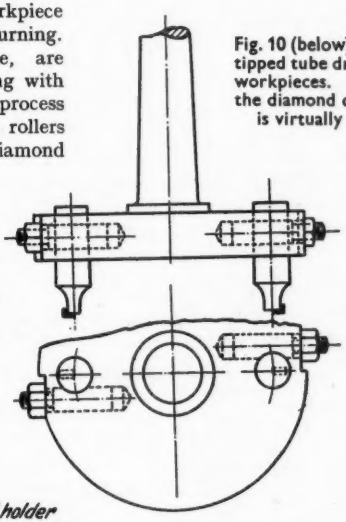
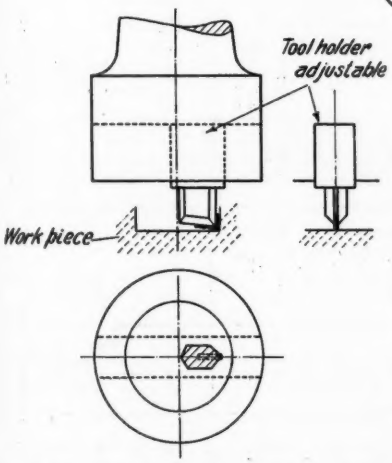
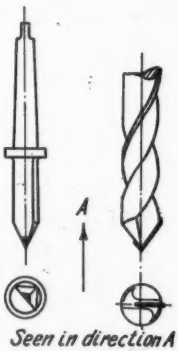


Fig. 10 (below).—Diamond-tipped tube drill for plastic workpieces. The life of the diamond cutting edges is virtually indefinite.

Fig. 9 (right).—Showing in plan and elevation diamond-tipped milling cutter for plastic workpieces. The nature of the cutting edge material in the case of tools of this type requires utmost attention to design, balance and means of adjustment.





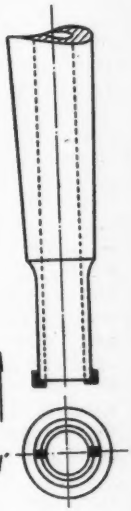


Fig. 11 (adjacent left).—Diamond-tipped twist drill for plastic workpieces. Fig. 12 (extreme left).—Diamond-tipped countersink for plastic workpieces.

turning, which is more rapid, more accurate and which produces definitely better finish. The idea has been suggested that soft rubber before turning might be frozen by dipping in liquid air. This would assist turning with steel tools for laboratory purposes, but can hardly be considered as suitable, at the moment, at all events, for production. Vulcanized rubber, particularly that of the harder grades, tends rapidly to destroy the cutting edge of a steel tool not only by direct abrasive action but also by result of chemical attack caused by the sulphur. Diamond tools are not affected either physically or chemically, however, in this way.

A comparatively important application of diamond turning is for the finishing of large calender rollers. No other tool

material is capable of withstanding the abrasive action of the hemp, asbestos, cotton-wool and jute fillers which must be encountered in completely traversing the roller from one end to the other. A diamond tool, however, may be used for this purpose for months without regrinding. Sometimes rake angles of considerably more than 3 degrees are used in this instance, and no dust is produced during the turning. The surface of diamond-turned calender rolls is smooth and accurate and, in normal circumstances, will last for about six months, although if subjected to heavy duty may deteriorate quicker.

Fig. 6 shows the turning of hard rubber discs by means of a diamond parting tool of 0.056 in. width. The diamond tool edge was bevelled and the cutting angles so chosen that the surface finishing of the discs was achieved in the parting operation. An application of this type is not restricted to hard rubber and similar insulating materials. Washers and distance pieces to highest limits of accuracy can be produced economically and accurately directly by means of parting tools.

Table 1.—Data on Machining of Non-metallic Materials with Diamonds.*

Material	Operation	Workpiece	Work size in inches	Cutting speed		Feed, in./rev.	Depth of cut, in.	Pieces per hour	Pieces before resharpening of tool	Extra finishing
				rev./min.	ft./min.					
Catalin†	Recessing	—	$\frac{3}{4} \times \frac{3}{16}$	6,500	—	—	—	600	Indefinite	None
Galalith‡	Circular milling	Bar	$\frac{3}{32}$ dia.	—	3,600	0.004	0.004	—	—	None
Celluloid	Turning	—	$\frac{1}{4}$ dia. × $\frac{1}{8}$	3,600	420	—	0.009	1,000	25,000	None
Celluloid	Reaming	—	$\frac{1}{4}$ dia. × $\frac{1}{16}$	3,600	200	—	0.010	700	100,000	None
Bakelite	Turning	Rod	$1\frac{1}{2}$ dia. × $\frac{1}{64}$	3,500	1,150	—	0.008	30	Indefinite	None
Hard rubber	Facing	—	$3\frac{1}{2}$ dia.	3,600	3,000	—	0.020	110	4,500	Buffing
Hard rubber	Reaming	—	$\frac{1}{4}$ dia. × $\frac{1}{16}$	3,600	200	—	0.010	1,800	50,000	None
Hard rubber (ebonite)	Parting§	Rod	—	—	250 to 600 and more	—	—	—	—	None
Rubber with cellulose and pumice	Turning	Typewriter roller	$1\frac{3}{32}$ dia. × $9\frac{3}{32}$	—	250	—	0.012	—	—	None
Hemp with asbestos, cotton-wool and jute	Turning	Calender rollers	—	—	250 to 400	0.016 to 0.024	0.020 to 0.048	—	—	None
Different non-metallic materials	Face milling	—	—	—	1,350	0.003	0.016	—	—	—
Copper and insulating material, probably mica	Turning	Commutator	$10\frac{1}{4}$ dia. × 12 $11\frac{2}{3}$ dia. × $12\frac{1}{8}$ 104 dia. × 12 56 dia. × 28	—	7,350 1,320 1,470 2,370	0.0016 0.0012 0.008 0.006	0.012 0.036 0.028 0.032	24 3 2.4 2.3	— — — —	None None None

* Partly taken from F. H. Colvin and F. A. Stanley, American Machinists' Handbook, 7th Edition, 1940, p. 366. Data from Arthur A. Crafts and Co. and Ernst Winter and Sohn. † Phenol-formaldehyde casting resin. ‡ Plastic moulding material of casein and formaldehyde. § Width of cut 0.056.

Fountain pen bodies are frequently diamond turned and bored, as also are high-grade mouthpieces for pipes. The hubs of laminated gears may also be similarly finished. Thread cutting and finishing of bearing surfaces in plastics, similarly, may be carried out with diamond tools. In the latter case it is interesting to note that whereas a perfectly smooth finish is obtained there is no smear or closing in of porosity and dimensions can be held to such fine limits that no running-in period is needed.

Tests by Lehr* showed that bearings fine-bored with diamond tools were capable of withstanding loads somewhat higher than usual.

Another operation for which diamond tools are suitable is sawing, which is sometimes performed with high-speed circular saws, set with four or more diamonds. Again, milling cutters with two or more inserted diamond edges are used for face milling, and diamond-tipped milling cutters, core drills, twist drills and countersunks are widely used for forming plastics in precisely the same manner as steel tools for wood or metal.

Recently, grinding wheels impregnated with diamond dust of various grain sizes are said to have found extensive use in U.S.A. for the process grinding of plastics and ceramics, but further details of this application are not yet available.

A special application of diamond "cutting tools" in connection with plastics machining is the use of diamonds in the production of sound grooves in gelatine and celluloid discs. A cutter with an included angle of 120 degrees is used for this purpose. A "structure-cut" diamond is required for this job and must present edges which are visually sharp at a magnification of 200 diams.; such a cutter may be assumed to have an infinite life. Diamonds are also used for hardness testing.

SOURCES OF REFERENCE

Fr. Nockold, British Patent No. 114,335. *W. Richards, "Machinery" (London), Vol.* 21, 1923, *pp.* 589-599. *P. Grodzinski, "Der Papierfabrikant," Vol.* 31, 1933, *pp.* 554-556. *P. Grodzinski, "Kunststoffe," Vol.* 23, 1933, *p.* 63. *A. Meyer, "Maschinenbau/Der Betrieb," Vol.* 13, 1934, *p.* 79. *W. Winter, "Werkstatt und Betrieb," Vol.* 68, 1935, *p.* 60. *P. Grodzinski, "Feinmechanik und Praezision," Vol.* 46, 1938, *pp.* 63-66.

Table 2.—Non-metallic Materials for Machining with Diamonds.

Material	Application	Trade names
Synthetic resins:		
Phenolic and cresolic, with and without fillers such as cotton wool, fibre, cellulose tissue, laminated textile and paper, asbestos, fire clay..	Bearings*	—
Phenol-formaldehyde	—	Catalin, Bakelite
Laminated plastics†	Hubs of plastic gears	Tufnol
Casein and formaldehyde..	Fountain pens	Galalith, Erinoid
Fibre	—	—
Celluloid	Gramophone records	—
Hemp with asbestos, cotton wool, jute	Calender rollers	—
Papier mache	—	—
Horn	—	—
Ivory	Billiard balls	—
Tortoise-shell	—	—
Mother of pearl	—	—
Special hard woods	—	—
Carbon	—	—
Graphite	Brushes for electric motors, electrodes	—
Mica	Commutators (with copper)	—
Gutta percha..	—	—
Soft rubber	Typewriter rollers	—
Hard rubber..	Fountain pens, mouthpieces for pipes, accurate electrical parts	Ebonite

* Ernst Lehr, Versuche mit Presstofflagern (experiments with bearings of plastic material), "Kunststoffe," Vol. 28, 1938, pp. 161–170.

† "Machinery" (London), Vol. 63, p. 334 (16th Sept., 1943.)

Winter and Sohn. † Phenol-formaldehyde casting resin. ‡ Plastic moulding material of casein and formaldehyde. § Width of cut 0.056.

World's Industry Employs Plastics

AIRCRAFT

Glass reinforced plastic fuselage, side panels and tail cone are embodied into new-type U.S. Army basic training plane which has recently undergone successful flight tests. Experimental plastic fuselage is of sandwich construction comprising a balsa core between an inner and outer skin of plastic reinforced with fibrous glass cloth. ("Automotive and Aviation Industries," 1944/90/29.) **Heating and ventilating systems** for aircraft now embody ducts built up of fabric asbestos and a coating of synthetic resin. The abolition of metal for this purpose reduces weight by 10 per cent. and gives equal strength and lower heat loss. **Protection of retractable landing gear from hot exhaust gases** is achieved by a new composite textile consisting of glass and asbestos. High strength and low weight, high resistance to abrasion and stability at high temperature and under corrosive conditions are claimed for the new material, which is manufactured by the Owens-Corning Fiberglas Corp. (Nicholas Tower, Toledo I, Ohio). **Core-filled resin** is used for the production of moulded screw bolts where high strength is called for, as in hoist tie-downs and mooring fittings. ("Automotive and Aviation Industries," May 1, 1944/p. 46). **Synthetic rubber base combined with small quantity of a so-called modified rubber,** produced by Firestone, gives a very adherent or what might be described as tacky body exhibiting improved bolt sealing properties for fuel and oil tanks on aircraft. This is an important point. Furthermore, it results in the conservation of natural rubber supplies. ("Automotive and Aviation Industries," May 1/1944/p. 46.)

GENERAL ENGINEERING

Drawing of synthetic fibres is discussed by Coppick in "Wire and Wire Products," 1944/19/238. Analogies between the production of metal wires and fibres are pointed out. The fundamental problem common to both operations is that of the uni-directional extension of the material. The article contains photo-micrographs of cross-sections of films, together with X-ray diffraction studies of such materials. **Nitriding steels for large dies for plastic moulding** have recently undergone considerable development, as described by Haufe in "Kunststoffe," 1943/33/151, also "Engineers Digest," 1944/5/139. **Rubber as an engineering material** forms the subject of a paper read by Moyal before the Leicester section of the Institution of Production Engineers. Emphasis is laid on the elastic properties of rubber and the possibilities of further developments as a result of the evolution of successful rubber-to-metal bonding processes ("J. Inst. Prod. Eng.," 1944/23/155, May). **Data on selection and specification of appropriate types of plastics for the engineer and designer** form the subject of a survey by Larson, of the Plastics Dept. of the G.E.C. ("Product Engineering," 1944/15/225). Technique of the moulding processes is explained, constructional data tabulated and mould costs and prices per lb. of common plastics are discussed. **Role of plastics** in so far as

they affect the tool-maker's art is explained by Price in "Tool and Die Journal," 1944/9/101 (March). The special characteristics of thermoplastic and thermosetting resins are analysed. Practically all the thermoplastic materials are flexible and bend readily up to sections at least $\frac{1}{8}$ in. thick; thermosetting materials, on the other hand, are much more rigid. **Standardized chemical testing methods** for the quality of modern plastics form the subject of recommended standards recently put forward by a subcommittee of the Plastics Committee of the Verein Deutscher Chemiker. The first publications refer to testing methods for polymerized vinyl chloride and plasticized mixes of this base ("Kunststoffe," 1943/33/297). Production of **moulded parts in Mipolam and other thermoplastics** by straightforward moulding, by the pressure-vessel method, by extrusion and by hammer pressing forms the subject of an account by Saechtling ("Kunststoffe," 1943/33/291). Injection moulding, dipping and plain casting methods are also referred to. **Wormwheels and heavy-duty nuts in plastics** employed in rolling mill construction have recently appeared in new designs, which are described by Eckberg ("Kunststoffe," 1943/33/295). The wormwheels have moulded-in plastic tooth bars embodied in a steel frame, whilst the nuts themselves are in steel with inserts of laminated plastic. Satisfactory service has so far been obtained. **The machining of plastics** forms the subject of the report by Zichle in "Kunststoffe," 1944/34/7. The following points are stressed: the contrast between machining of plastics and machining of metals, use of sintered carbide, use of high-speed machine tools. The influence of resin type and problems in connection with sawing, drilling, tapping, turning, grinding, milling, shaping and punching. **Stress analysis by the "frozen-in plastics" pattern method,** using a phenolic resin model subsequently sectioned for observation under the polaroscope, is discussed in general terms by Frocht in "Journal of Applied Physics," 1944/15/72. The author considers general problems arising in the analysis of three-dimensional photo-elastic diagrams. Model shafts were investigated principally, the material used being BT-61-893; specimens were 7 ins. long, 1 in. diameter, heated to 260-265 degrees F. 2-3 hours and cooled slowly under load for 12-14 hours. **New synthetic resin** for use in conjunction with the monomer styrene for the treatment of porous castings in magnesium and other metals is being produced by Ault and Wiborg, Cincinnati, Ohio. It is stated that the co-polymer formed is insoluble in petrol. ("Automotive and Aviation Industries," 1944/90/60.) **Butyrate plastic** is used in the construction of a new torch issued to the U.S. Army Air Force, the lamp being housed at the end of a flexible metal tube. The same plastic is also employed for shatterproof windows, in pressure gauges, for boilers and air-conditioning units.

ELECTRICAL

Dielectric strengths, dielectric constants, power factors, resistance to arcing and insulating strengths of plastics are dealt with by Larson in "Product Engineering," 1944/15/329. The author points out the wide range of properties covered and observes that, by the use of graphite or metallic fillers, resins, which are nominally insulators, may be transformed into partial conductors. Tables and diagrams are given. **Influence of thin oil film** on the electrical behaviour of Trolitul, Plexiglass and Vinedur at various degrees of humidity was recently investigated by Vieweg and Gottwald at the Institute of Physics, Darmstadt. A distortion method in conjunction with an electrometer was employed. ("Kunststoffe," 1943/33/289.)

CHEMICAL

Filtering material known as Multipore is produced from natural-rubber latex. It contains as many as 6,400 perforations to the square inch. Filter screens of this material developed by the U.S. Rubber Co. are available in either hard or soft rubbers and may be compounded for high abrasive resistance, high temperature resistance and resistance to attack by alkaline or acid solutions and certain oils and greases used in chemical engineering. ("Machine Design," 1944/16/96.) **Collapsible protective container** designed for wrapping round glass or metal containers holding corrosive chemicals in transport has been developed by the United States Rubber Co. It consists of two sheets, one of light cotton fabric treated with vinylite and another coated with synthetic rubber. The two are placed together, cut into a circular form and linked by eyelets and a cord. **Sulphur plasticized with Thiokol,** produced under the name "Tegul C Vitrobond" by Atlas Mineral Products Co., has recently been placed on the market as an acid-resistant structural material. It is employed for mortars and allied chemical plant for the production of explosives, pigments and certain types of synthetic fibre. The material is inert to hot or cold mineral acids, is not attacked by corrosive inorganic salts or mild alkaline solutions; it is stable up to temperatures of 200 degrees F. It will, further, bond to brick with a strength of 400-500 lb./sq. in. and has high resistance to abrasion; it may be used satisfactorily both as a cement and material for the building of acidproof floors ("Scientific American," 1944/170/276). **Trade name "Geon" of the Goodrich Co.** covers a series of special polyvinyl resins. The Geon 100 series refers to special vinyl chloride polymers highly stable to light and heat.

MISCELLANEOUS

Drying of phenolic-resin lacquers has been studied in a series of comparative tests by Saatmann (Osram Lichtheft, 1943/19/47: abstracted in "Elektrotechn. Z.," 1943/64/661), who showed that in thin films these lacquers take four times as long to dry by ordinary stoving methods as opposed to infra-red drying methods. Infra-red drying is not only very rapid but also yields films of high quality. **Plasticizer designed to modify GR-S synthetic rubber** and make it behave more like natural rubber is stated to have been developed by Du Pont de Nemours. Synthetic rubber forms the subject of a 70-page booklet issued by Acadia Synthetic Products Division of Western Felt Works, U.S.A. Photographs and data on resistance to low temperatures, hardness, resistance to heat and ageing are given. **Advantages of high-frequency heating** as compared with conventional methods for the curing of laminates is discussed in "Product Engineering," 1944/15/299. The author analyses the subject in detail and points out that the first observation of importance in this connection was made by Siemens in 1864 when he recorded the heating of the glass wall of a leyden jar whilst charging. Formulæ are given for determining the heat developed in a material, voltage, frequency and electrical characteristics of the material being known. **Transparent plastic pill box** is being employed for sulphur pills to enable contents to be inspected regularly and with ease and to guard against effects of damp ("Scientific American," 1944/170/249). **Synthetics produced from petroleum and natural gas** are also reviewed in the same issue. It is observed that to date some 160 compounds have been placed in regular production, using these raw materials.

The CLEANING of PLASTICS

(Continued)

With Special Reference to Cleaning After Fabrication Processes

By E. E. HALLS

HAVING discussed (July, 1944, issue) the solvents in detail with respect to their properties, it is time to turn to the plastics, with brief recommendations beyond those already specifically given.

Dealing first with the phenolic resin materials, which include cast resins, laminated (paper, fabric, asbestos and woven glass bases), mouldings (wood filler as well as flock, asbestos or mineral loaded), it will have been apparent that any of the range discussed can be used, but some are more efficient than others. Of the inflammable solvents, medium naphtha is preferred. Light benzine is very good indeed, especially if rapid drying off, without air blast, from intricate shapes is required. An inexpensive, high hydrocarbon content cellulose lacquer diluent is also quite sound, and can be adopted if more readily available in the factory. Methylated spirit is useful for watery contamination, or 50-50 methylated spirit-solvent naphtha mixture for combined oil and water contamination. These are all suitable for general contamination or for cleansing prior to organic finishing. If convenient, it is quite good practice in the last instance to use naphtha prior to varnishing or enamelling with oil base or synthetic media, and cellulose thinners if cellulose finishes are entailed.

In all cases of immersion cleaning, rapidity of processing is stressed: the minimum time of contact with all solvents is advocated in order to minimize the possibility of absorption. This precaution is the most desirable with paper and fabric laminated units, and of minor moment with mineral-loaded mouldings.

If phenolic resin components are not fully cured, the methylated spirit and acetone will have some solvent action, more or less slight, upon them, and may cause a rough surface, although it may not be unduly pronounced.

Comments given in relation to the phenolics appertain to the other thermosetting resin products, the chief being those of the amino group.

It is pointed out that trichlorethylene is all important because of its non-inflammability. A standard type of liquor vapour degreasing plant is very useful for practically all cases of thermosetting resin products. It is important to minimize treatment times both in the liquid and vapour sections. Proper maintenance of the plant is also stressed. Adequate control on the steam line or electric heaters, to ensure no temperature rise above 125 degrees C., must be maintained, otherwise some decomposition of the solvent into acidic vapours can occur. Regular cleaning of the equipment at frequent intervals in accordance with the amount of contamination entering is essential, otherwise overheating to secure boiling is resorted to, and "cracked" oil vapours are produced. These often leave the work in a worse condition than its initial state.

Removal of Fluxes

As earlier mentioned, the trichlorethylene method is ideal for the removal of resin solder flux. Alternatively, methylated spirit is necessary for this, but a longer soak may be required.

When corrosive fluxes have to be used on metal inserts, naturally every precaution has to be taken in their selection and

use. This may be assumed for the present purpose. These fluxes run freely under the heat of the iron, contaminate the plastic surface and even become absorbed to some degree. This is most marked in low grades of phenolic laminated (on which the practice should be avoided), and much less marked on the moulded phenolics. If aqueous fluxes, such as killed spirit or zinc chloride solutions, or aqueous-alcoholic glycerine-zinc chloride mixtures, are employed, they must be very thoroughly removed by water washing. Two water washes are necessary, and they can preferably be warm, from 50 to 100 degrees C., according to the fragility of section and grade of product. A rinse in methylated spirit before drying off is highly desirable. When electrical stresses are relatively high and terminals closely positioned, for the final rinse it has been found highly beneficial to use acetone for assurance that a leakage path of low insulation is not left. There are a large number of examples of small mouldings of complex design having closely positioned inserts, e.g., spool heads of small coils and moulded assemblies where such practices are adopted with success.

Washing in Special Cases

Sometimes the more complicated jelly fluxes are used because they are more convenient to employ, less likely to be splashed or handled over the work, less prone to run, and less penetrative under the heat of soldering. They are, however, more difficult to remove. They consist of mixtures of petroleum jelly, resin, zinc chloride and the like. The jelly should first be removed in trichlorethylene or in solvent naphtha (the first also removing resin), and then the remainder of the flux removed by double washing in methylated spirit. In fact, with complicated assemblies, the spirit wash is often followed by water washings, and then again by spirit or acetone. It is evident that the simplest procedure that is effective must be designed to suit each type of component, or an average treatment used that is suitable for the worst case.

It is apparent that resin or resin-alcohol solutions should be adhered to as far as possible to avoid these intricate but essential washing operations. Nevertheless, they do become necessary in practice more frequently than would be thought at first sight, not only with moulded inserts but also on wire windings, e.g., coils on phenolic paper laminated tubes, resistance windings on phenolic asbestos laminated formers, etc., etc.

Where resistance-less contact is required, a final wash after completion of all assembly operations is given, this wash being confined as far as possible to the contact areas. At power frequencies, examples are precious metal contacts, usually mounted on springs, in which case local cleaning should be possible without fouling any neighbouring plastics. The latter may be phenolic laminated cheeks or separators, or moulded components. At radio frequencies, it is very often an actual copper winding upon a phenolic paper laminated tube which serves the former for the coil; the copper is usually silver plated, silver clad, or silver and rhodium plated. The object is perfect point contact. The light benzine or one of the cellulose thinners is satisfactory for cleaning, but more usually a non-flam solvent is necessary because of conditions in the shops where the cleaning is performed. Carbon tetrachloride is, therefore, the commonly specified solvent for several good reasons. It can be purchased in small quantities in glass bottles, such as Winchester quarts, in which its cleanliness can be assured. It is a good universal cleanser and evaporates rapidly, and experience shows it to be very effective for the purpose. On the other hand, it must be kept dry and, as far as practicable, not exposed to light. Further, its toxicity must not be overlooked. Typical test results representing the grades of carbon tetrachloride used are as under:—

Specific gravity at 15.5°C. ..	1.608
Boiling point	75°C.
Residue on evaporation	Nil
Acidity (in terms of milligrams of potassium hydroxide per grm.)	0.01
Acidity, expressed as hydrochloric acid per cent.	0.0006

Regarding the thermoplastic materials, a cold cleanse is necessitated by virtue of their melting - point limitation. Trichlorethylene degreaser plant cleansing is therefore out of the question, and this solvent has to be employed cold in the same way as the others, bearing in mind, of course, that it is entirely unsuitable for some thermoplastics.

The Cellulose Plastics

For cellulose acetate (rod, sheet and tube products, or mouldings, or cellulose acetate coatings), a hydrocarbon solvent is suitable, light benzine or medium coal tar solvent naphtha being usual. As this plastic is soluble in acetone and ketones, and in many esters or ester spirit mixtures, the cellulose thinnings are unsuitable. With assurance of their composition, certain types can safely be used, e.g., the amyl or butyl acetate/hydrocarbon mixtures.

Ethyl cellulose is closely similar to cellulose acetate. It is soluble in ketones and ester, and in mixtures of coal tar hydrocarbons with methylated spirit. The best cleaner is light petroleum.

Polystyrene, Methacrylate and Polythene, etc.

Polystyrene is very easily soluble in coal tar hydrocarbons, and therefore solvent naphtha is entirely unsuitable; hydrocarbon solvents including the petroleum products are usually avoided. Cellulose solvents are unsuitable or dangerous because of their hydrocarbon ingredient, this being coal tar naphtha in at least 50 per cent. of cases. It is also soluble in trichlorethylene so that chlorinated hydrocarbons are also taboo. Industrial methylated spirit is satisfactory and is usually used. As the polystyrenes are unaffected by water, this can also be employed, especially if a soap solution has been used as lubricant. However, a final rinse in methylated spirit is necessary to assist in drying off.

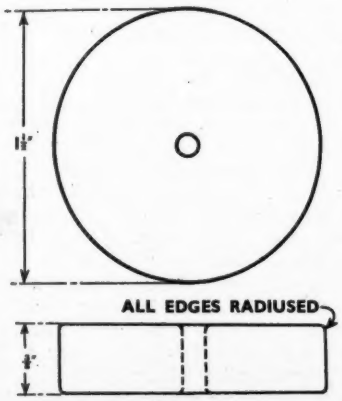


Fig. 9.—Machined polystyrene component for radio-frequency applications.

Fig. 9 shows a close dimensionally limited component machined from sheet or rod, and required to have perfectly finished faces. It is one component on which many hours of expensive machining were lost through final washing in coal tar naphtha. The effect of the latter, merely 10 to 15 secs. immersion, was to stick the components together in a mass, to roughen up edges and faces, and generally to render them useless.

Methyl methacrylate plastics (e.g., Perspex, Diakon, etc.) represent another group for which the selection of solvent cleanser must be closely watched. Choice of lubricant, too, must be careful because all solvents have some effect; the solvent with least action must be employed, and, therefore, a lubricant that can be removed by means of such a solvent has to be used.

The methyl methacrylates tend to be soluble in coal tar hydrocarbons such as toluene; therefore solvent naphthas cannot be used indiscriminately, although experience shows that the medium grade is safe. It is soluble in ethylene dichloride, trechlorethylene and the like, and therefore chlorinated hydrocarbons are excluded. It is soluble in acetone and esters, thus precluding the use of the cellulose lacquer thinners. Ethyl alcohol is a non-solvent for methyl methacrylate, and therefore industrial methylated spirit should be a possibility, but experience shows it does not provide a satisfactory solution. Also the material is virtually

unaffected by water, and this solvent therefore represents one available for cleaning this plastic.

The inclusion of plasticizers may cause increase in solvent attack, and this has to be borne in mind with all the thermoplastic materials.

Fig. 10 shows a methyl methacrylate moulding having a hexagonal brass insert with blind hole which required tapping after moulding. A practical trouble was experienced in washing free from swarf and lubricant in as far as solvent naphtha was specified for the cleaning, yet the product was ruined, the bulk becoming sticky, cemented together and irrecoverable. Investigation into various solvents that were available to the machine shop concerned revealed the following facts.

(a) Coal tar solvent naphtha actually had very little deleterious effect except with prolonged immersion. Complete immersion for 15 mins. caused loss of lustre but no rounding of sharp edges.

(b) Cold trichlorethylene exerted an immediate solvent action upon the mouldings, which quickly became soft and sticky.

(c) Inexpensive cellulose thinners of low ester content and high percentage of coal tar naphtha diluent caused more deterioration than solvent naphtha. In 5 mins. immersion the mouldings became sticky and soft.

(d) Industrial methylated spirit produced some softening of completely immersed samples in 10 mins., and surface whitening in an hour. The deterioration was then rather more serious than with solvent naphtha.

It was concluded that the particular trouble was caused by the use of the wrong solvent, either cellulose thinnings had been used and an excessive immersion time allowed, or more probably a trichlorethylene degreaser had wrongly been used for convenience; or again, if solvent naphtha had been employed it had been contaminated with other solvents. No further troubles arose when solvent naphtha was used and a maximum immersion time of 1 min. was stipulated. It was also ensured that the work was blown dry with a blast of clean air as soon as possible after removal from the solvent.

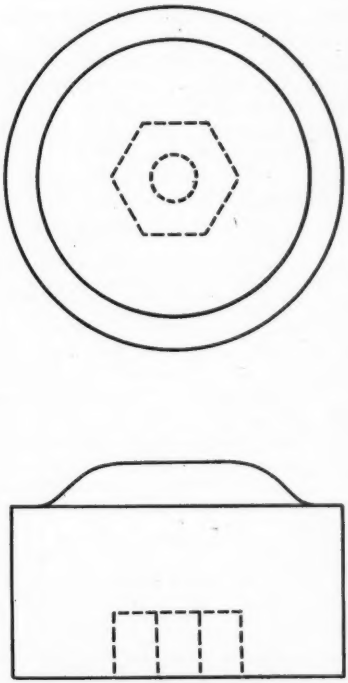


Fig. 10.—Methyl methacrylate moulding with brass insert.

Incidentally, the majority of methyl methacrylate is machined dry, and water is the most usual, and the recommended, coolant. Soap is advocated for drilling the larger holes (say, greater than $\frac{1}{8}$ in. diameter). This means that water has to be used for washing, and it may give some extra trouble in drying off, although the use of warm water assists.

The polyvinyl chloride products appear as sheet and tube products, as mouldings and as sleevings. Their properties may be much varied by plasticization or by co-polymerization with polyvinyl acetate. In general, however, it can be said that petroleum solvents are safe. Coal tar hydrocarbons cause swelling, while

ketones (e.g., acetone) and esters may exert from slight to appreciable solvent action. Methylated spirit is the general purposes solvent used for cleaning. Closely similar remarks appertain to the polyvinylidene chloride products, methylated spirit serving as cleaner.

Polythene is virtually insoluble in cold solvents, but it is soluble in hot coal tar and petroleum hydrocarbons, and in the chlorinated hydrocarbons. It is usually cleaned when necessary in cold methylated spirit, although it is insoluble in acetone as well as in ethyl alcohol.

The various forms of casein plastic are really insoluble in solvents, although extended immersion in some of them may cause swelling. Water is worst in this respect, and methylated spirit can be regarded with suspicion. The medium coal tar solvent naphtha is a satisfactory cleaner to employ.

Treatment of Ebonites and Rubbers

Finally, the wide range of ebonites, not only the black ebonites, but also the various so-called "composite insulating materials," which are silica or otherwise mineral-loaded ebonites. They are all fully vulcanized rubber-base materials, and the medium coal tar solvent naphtha is preferred for cleaning free from swarf and contamination. Some operators use methylated spirit quite satisfactorily, but there is a suggestion that this can leave a surface film of low insulation. A warning can be given that trichlorethylene is dangerous because it promotes deterioration, cracking from holes and edges, small pieces of ebonite often breaking away. Soft rubbers rarely come into the picture. Peculiarly, trichlorethylene seems quite safe for degreasing them, even when using a hot vapour degreaser. In many cases, for the removal of surface contamination in the nature of french chalk and the like, scrubbing with soap and water, with final water washing, is apt. When sticking is entailed, as when using the various special rubber cements, carbon tetrachloride is often used, but actually the coal tar naphtha is the best medium. A very thorough clean is desirable in this application.

Comments have been made in the foregoing on selection of a lubricant that can readily be removed. This is obviously important. Difficultly soluble fats must be avoided. Soap-base greases and oils, not only the thick hard soap greases, but even the emulsion oils that have a soft soap emulsifying base, and which are used diluted with water, should not be used. Not only are they difficult to remove by washing, and often impossible to eliminate completely, but there is always the probability that an alkaline film is left when cleaning under production conditions. Therefore, they are obviously dangerous when electrical plastics are involved, both when used at high power voltages or when employed at radio frequencies.

Some tabulated data are given appertaining to the normal lubricants available for arduous operations in engineering machine shops. Table 12 refers to the sulphurized cutting oils that are employed on high-speed automatic machines for turning and cutting. They represent perhaps the highest grade of liquid lubricant capable of being continuously fed by pump circulation. They are used from neat to a dilution of one part to 40 parts of mineral blending oil (see Table 13). They are completely and readily soluble in the solvents discussed, and are therefore easily removable by washing.

For severe tapping operations, perhaps the various lard oil, wool fat, mineral oil mixtures are most generally used to-day. They are represented by the examples given in Table 15. They, therefore, seem the most logical choice when lubricant is really required for difficult tapping operations, as in some of the mineral loaded mouldings and sheet materials. They are easily soluble. Actually, however, the aluminium soap-base greases shown in Table 14 are preferred. They are straight mineral oils, having their viscosity and adhesion properties improved by the inclusion of a small percentage of aluminium soap. They are completely soluble in hydrocarbon sol-

Table 12.—Characteristics of Sulphurized Base Cutting Oils Used for Tapping and Drilling.

Sample No.	1	2
Acid value, mgms. KOH/gm.	6.0	3.9
Saponification value, mgms. KOH/gm.	30	34
Ash on incineration, %	Nil	0.02
Iodine value, WIJS.	16	23
Sulphur content, %	0.7	1.8
Viscosity, Redwood, seconds		
At 70°F.	550	750
At 140°F.	69	75
At 212°F.	29	41
Specific heat	0.54	0.52
Flash point (open) °F.	345	350

Table 13.—Characteristics of Light Mineral Blending Oils.

Sample No.	1	2
Acid value	Nil	Nil
Saponification value	Nil	Nil
Ash on incineration %	Nil	Nil
Iodine value, WIJS	11	13
Specific gravity at 15.5°C.	0.894	0.903
Specific heat	0.57	0.56
Flash point (open) °F.	280	340
Viscosity, Redwood, seconds:—		
At 70°F.	188	250
At 140°F.	49	53
At 212°F.	36	37

Table 14.—Analysis of Typical Aluminium Soap Base Tapping Greases.

Sample No.	1	2	3	4
Composition per cent.:				
Ash (aluminium oxide)	0.36	0.52	0.53	0.80
Fatty acids (as aluminium soap)	4.4	6.6	6.4	7.9
Mineral oil	86.0	85.2	87.1	84.2
Fatty acids as glycerides	9.2	7.7	6.0	7.1
	100.0	100.0	100.0	100.0

Table 15.—Characteristics of Tapping Oils having Lard Oil/Wool Fat Base.

Sample No.	1	2
Acid value, mgms. KOH/gm.	2.4	1.6
Saponification value, mgms. KOH/gm.	128	73
Ash on incineration %	Traces	0.01
Approximate composition %:—		
Mineral oil	Nil	48
Lard oil	25	26
Wool fat	75	26
	100	100
Viscosity, Redwood, seconds:—		
At 70°F.	225	198
At 140°F.	64	61
At 212°F.	41	36

vents, and so components upon which they have been used can easily be cleaned free from them. They have not been available on the market in recent years, but it is hoped that they will shortly be again available.

Incidentally, it is hoped that a range of lubricating oil and greases will be commercialized, these compounded from straight lubricating oils and aluminium naphthanates. They hold great promise as lubricants, easily removable, free from fats that may turn rancid, and, in manufacture, simple to control.

Table 16 gives data on tallows which are extensively used in spinning and in vertical tapping operations and strongly favoured by operators in tapping plastics especially the phenolic mouldings. The higher melting point tallows show better lubricative qualities than the lower melting varieties. Being solid, they are exceedingly difficult to remove by means of solvent, even when using hot trichlorethylene degreasing plant. Residues left can be very corrosive to metal such as brass inserts.

At the risk of digressing at this stage,

Table 16.—Laboratory Characteristics of Tallows.

Sample No.	1	2	3	4	5	6
Acid value, mgms. KOH/gm.	10.0	9.2	5.0	9.3	1.8	15.5
Saponification value, mgms. KOH/gm.	190	193	194	195	192	194
Melting point °C.	50	50	45	48	43	44
Viscosity, Redwood, seconds:						
At 140°F.	111	109	98	101	92	92
At 212°F.	52	51	50	50	48	47

a general review of American practice to see how far lubricants are used or avoided in that country may be of interest.

American Lubricating Technique

Information on latest American practices in the machining of plastics is given by W. S. Low, "Iron Age," February 10, 1944, and is taken from the 1943 edition of the Plastics Catalogue.

For turning cast resins, a bronze tool bit is used in small production and requires dressing after 100 to 150 cuts. For quantity production, high-speed steel tools are preferred. Whichever tool is used, it must be carefully honed in order to produce smooth cuts. On work requiring polishing, this is advantageous because the work can go straight from the machine to the polishing operation without intermediate sanding. The majority of work is machined dry, and although coolants are rarely required, when they are used, they must be of the non-alkaline type.

For turning, tools are sharpened as for brass. Ample clearance is given, 10 degrees to 20 degrees, and a slightly negative or zero rake is desirable. The tool is set at right angles to, or 1 degree to 2 degrees above, the centre of the material, and cutting edges should be finished in a condition to produce long ribbon shavings. Special grades of tool materials are not required, although hard bronze tools are employed and these can be filed without removing from the holders. Stellite, cemented carbide or high-speed tools are used when it is desired to obtain longest possible runs and minimum of delay for resetting and resharpening. Spindle speeds in turning range from 450 r.p.m. to 6,000 r.p.m., these being determined by the type of work and the diameter of the material. They should be regulated to a surface speed of the order of 600 ft. per min.

For the laminated plastics and vulcanized fibres, closely the same rules apply as for machining brass. Highest possible speeds and sharp tools are desirable. Slow speeds cause very rapid dulling of the tools. Cemented carbide tool tips, such as Carboloy, are specially recommended for turning and boring on account of higher speeds and less grinding that they necessitate. Clearance should be at least 30 degrees. This caters for the slight elastic nature of the tool and the tendency to spring back with a generation of heat and the dulling of edges. It eliminates abrasive rubbing action to a considerable degree. Tubes and rods of these materials are successfully machined in automatics or in hand-screw machines. It is stressed that tubes are not exactly concentric, and drilling the inside when concentricity is required is advised.

Recommended cutting feeds on automatics are as follow:—

	Feeds in. per rev.
Drilling	0.007 to 0.015
Turning	0.010 to 0.015
Cutting off	0.002 to 0.005
Forming	0.002 to 0.003

Water-hardened steel is used for form tools because of increased hardness and the length of run between grinds. Carbide tips for cut-off tools are warranted. Spindle speeds for various stock sizes are shown below:—

Hand-screw Machines

	R.p.m.
1 in. diam. and over	800 to 1,000
Under 1 in.	1,500 to 2,000

Automatic Machines

	R.p.m.
Larger than $\frac{5}{8}$ in. diam. ...	2,500
$\frac{7}{16}$ in. to $\frac{5}{8}$ in. diam.	3,600
$\frac{1}{4}$ in. and less	5,000

For drilling holes up to $\frac{3}{16}$-in. diam. the normal standard of high-speed drills with a slightly negative rake ground on the cutting lip is satisfactory. Very high speeds are advocated and the drill should be backed out to avoid burring. Speeds are from 2,800 to 12,000 r.p.m. for small holes, or 100 to 300 ft. per minute, but when the material has high abrasive qualities, this speed is reduced to about 75 ft. per minute. It is useful to keep the tool cool by directing a thin jet of compressed air as near the hole as possible and directly on to the drilled hole.

Specially designed drills for plastics should be used for holes larger than $\frac{5}{16}$ in. Flutes are highly polished and maximum chip appearance provided for with a slow helix for pierced holes and a fast helix for blind holes, with a 55-degree point for thin sections and 90 degrees for thick sections. A slight radius at the end of the lip is provided and helps to maintain hole sizes. The tendency to cut holes undersize requires close watching.

For the drilling of methyl methacrylates, a drill is recommended having a flute angle of 17 degrees and a lip angle of about 70 degrees and a lip clearance angle of 4 to 8 degrees. The lands should be polished one-fourth of the width of the heel. Lubricants for drilling help to remove chips, carry away heat and give improved finish. Warm soap solution is recommended, although oil is stated to be quite satisfactory. It, of course, gives extra cleaning problems.

High-speed drills are recommended and drilling at the highest possible speed without burning the drill. For a $\frac{1}{4}$-in. drill, 2,500 r.p.m. give best results and for a No. 60 drill 10,000 r.p.m. are not excessive. Dubbing the lip of the drill and giving it plenty of clearance enables it to cut freely and prevents splitting and grabbing. Drills must not be forced and only slight pressure is necessary if they are kept sharp.

Reaming is not usually recommended and, when necessary, expansion reamers with self-centring floating holders are advocated. Speeds not exceeding 50 to 100 r.p.m. with very fast feeds are used. Often a hole can be sized by drilling within 0.001 in. and then passing a highly polished hardened rod through it.

Regarding threading, the general practice is to mould threads above $\frac{1}{4}$-in. diameter and tap smaller ones. Threads smaller than No. 8 or finer than 36 threads per inch are not moulded because fine or shallow threads tend to fill with pure resin and are very brittle. Under the conditions recommended, moulded threads are stronger than tapped threads. It is recommended that moulded threads should not be retapped. In some cases threads as fine as 56 threads/inch can be tapped. Mineral-filled compounds are brittle and difficult to tap, and fabric-filled materials tend to swell under moist conditions due to exposure of the fabric at the cut edges.

For the cast resins standard taps can be used, but ground high-speed steel taps have proved more satisfactory, whereas chromium-plated taps are recommended for long production runs. Very little rake and plenty of clearance are essential. The effect of abrasive materials and binding can be minimized if clearance is ground on the sides of the threads and taps with three instead of four flutes give longer tap life.

Regarding speeds, 40 ft. per minute is recommended for 0.736-in. taps and 54 ft. per minute for 0.0590-in. taps. For cooling, water has proved more efficient than oil or paraffin, but tapping dry is normally recommended and said to cause the least wear.

For laminated plastics and vulcanized fibres, high-speed taps oversize to 0.002 to 0.005 in. are recommended and it is interesting to note that a little oil is considered helpful. Three thousand holes can be threaded in $\frac{1}{4}$-in. material using 10/32 tap without resharpening. Another interesting point is that it is claimed that a drill for 75 per cent. full thread facilitates tapping and cuts down the tap breakage. Further, a slight chamfer round the hole before tapping assists in preventing uplift around the hole. Collapsible taps are used for holes larger than $1\frac{1}{4}$ in. or $1\frac{1}{2}$ in.

External threads in mouldings may be produced by moulding in split halves. The thread may be from 0.005 to 0.015 in. out of round and will have a slight ridge across the threads. In threading or tapping the methyl methacrylates to accommodate metal bolts or nuts, allowance is made for the difference in the coefficient of thermal expansion of the two materials. A slight increase over normal metal clearance is usually suffici-

ent. Hand or machine tools are used for threading or tapping. The material can also be machined in lathes or automatic machines. Standard taps are employed. The tap or die is operated at a speed of about 25 per cent. slower than for brass or for cellulose plastics. Excessively high speeds cause frictional heat and the sticking of chips, so that taps should be backed out frequently to prevent jamming.

For hand-tapping holes smaller than ¼ in. it is not essential to use a lubricant. For larger holes a mild soap solution for drilling is recommended. When machine tapping or threading, the work requires to be flooded with lubricant, and lubricant also assists to produce a smooth, accurate result when tapping by hand.

For milling operations, carbide-tipped tools are recommended for long-production runs. Cutting speed is of the order of 400 ft. per minute, but if cuts are very light, greatly increased speeds may be used. Carbide-tipped cutters permit of up to 1,000 ft. per minute. Slow feeds promote smooth finishes. The cutters must be kept exceedingly sharp and honing the teeth to a very smooth edge is important.

Abrasive wheels for cutting off are usual with high spindle speed. A flood of water is used as a coolant. Sawing is performed at about 1,200-1,300 ft. per minute and best results are secured with a band saw of 14 to 18 teeth per inch. When using a jig saw, a No. 3 jeweller's blade with 22 teeth to the inch for intricate work and a No. 4 or 5 blade for normal production and for stacked work is usual. Thin methacrylate sections are individually sawn without a lubricant and likewise thick pieces can be sawn slowly without lubricant. Lubricant does, however, eliminate or reduce possibility of chipping and gives cleaner cuts and eliminates the tendency of the saw to stick. For heavy cuts, including stacks of thin section, the lubricant eliminates the tendency to smoke. The best lubricant is water, but oil can be employed if it is essential to eliminate the possibility of rusting. Special practices use oil paper between the stacks and bar soap is also resorted to.

Grease burnishing is a finishing process in which the barrel is loaded with three parts of pegs and two parts of articles, and a mixture of grease, sawdust and precipitated chalk is used. The quantity of the latter ingredients is controlled to minimize the grease film and the time of operating.

Dry tumbling is similarly carried out, using very fine pummice and paraffin oil. War finishes are obtained by barrelling with wax to the extent of about 1 per cent. on the quantity of pegs used, the hot wax being added to the pegs in the barrel before the work is introduced. For methyl methacrylates, a mixture of carnauba wax and beeswax is used and is previously dissolved in turpentine.

Wheel finishing by grinding and buffing are employed, and in grinding it is essential to use plenty of cutting compound, paraffin or soluble oil, in order to wash the grindings free from the wheel.

Cleaning of Oil, etc., from Plastics

In general, for the cleaning of oil and swarf from plastic components, a separate room or enclosure is set aside, in which the inflammability and toxicity of the solvents employed can be properly taken care of by means of suitable exhaust and ventilation. Obviously, such practice in every case is not necessary, nor is it always practicable. It is desirable when dealing with small components in bulk. These are best treated in baskets or, for fragile articles or larger items, on hooks, jigs or frames. Handling should be so planned that it is unnecessary for the solvent to contact operators' hands. All the solvents are relatively "harmless" in this sense, but naturally, being grease-solvents, they withdraw fats from the skin and cause dryness, chaps or even sores with some people. Baskets should be made from wire mesh as open as the work permits. The solvent dip tanks should present the minimum of surface area to reduce losses from evaporation.

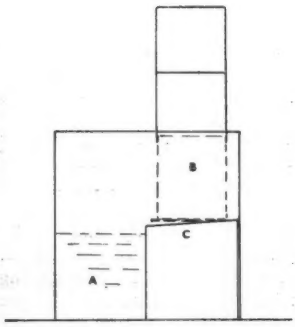


Fig. 11 (left).—Showing immersion tank for spirit washing. A, solvent; B, open-mesh basket on ledge in draining section; C, sloping bottom of draining section.

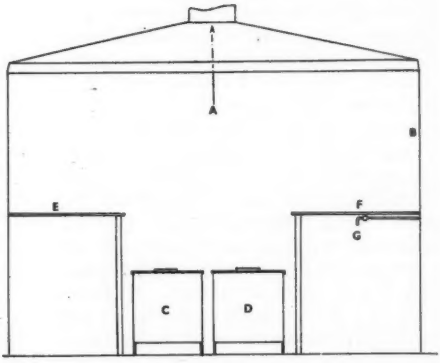


Fig. 12 (right).—Arrangement of spirit washing station. A, exhaust; B, glass sides to booth; C and D, washing tanks with loose covers; E and F, work benches, bakelite covered; G, air point.

Ample depth of solvent should be used to avoid stirring up the accumulated swarf and to permit of hanging the basket within the confines of the tank, but above the solvent level for draining purposes. If two baskets per tank are employed, then the draining section can be to one side with a sloping bottom to the main tank, as shown in Fig. 11. Two solvent tanks are used in series, the second for a final clean rinse. The second becomes the first when the latter is due for scrapping. It is convenient to make these tanks sufficiently small to facilitate handling and pouring the scrap liquor away via a lip at the top. Larger designs have to be provided with a drain-off plug.

Tanks should be installed with the top edges at bench level, either sunk into the bench on low benches or on stands. They can be arranged under a large hood fitted with a volume fan, and final blowing off with compressed air when resorted to can be done alongside, so that all organic solvent is exhausted through the same plant. The enclosure should be provided with fresh air to compensate the outgoing exhaust, either by windows from the outside atmosphere or fed from an air-conditioning plant.

Lights can be installed in convenient positions for the operators to see what they are doing. It is usual to fit flame-proof lights within the booth. All lights and switches should be of the flame-proof type.

The general arrangement of the cleaning booth is shown in Fig. 12.

If a trichlorethylene degreasing plant is also used, there is no reason why it should not be installed in the same cleaning enclosure provided it is of the steam-heated variety. If gas or electric it must be positioned elsewhere on account of fire hazard. The size and capacity of the trichlorethylene cleaning plant will be determined by the nature and volume of work to be cleaned. Fundamentally it consists of a tank in the bottom of which is a reservoir of solvent. This can be heated to boiling by means of steam coils passing through it, or by electrical heaters or gas burners from the outside. The top of the tank is kept cool by a channel through which water is circulated to form a cold line. Further, egress of vapour is prevented by a bank of cold water coils inside the tank around the walls. Under correct operating conditions, these maintain a horizontal cold layer below which is hot trichlorethylene vapour. In

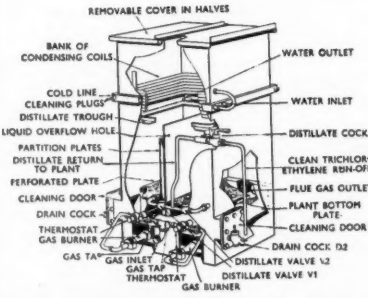


Fig. 13.—I.C.I. trichlorethylene degreasing plant and connections for the gas-heated type.

combined liquor, vapour plants, arrangements are made for a reservoir of liquid in one half of the tank, this liquor being constantly refed with clean solvent from the condensate on the cooling coils. The general principle is illustrated by Fig. 13, of liquor-vapour degreasers, this being taken from the I.C.I., Ltd., catalogue.

These small degreasers, vapour only or liquor-vapour type, are the most generally useful, although special designs can always be erected to suit specific needs. Some workers use a vapour degreaser in conjunction with a stationary tank of cold trichlorethylene. The latter is used for a preliminary rinse to remove solid dirt, and this has no objections provided the tank is kept covered when not in use.

As the solvent becomes contaminated, its boiling point rises, dependent upon the nature of the oily contamination. Fig. 15 is a typical average curve showing this increase. If heat is supplied to achieve boiling, it is evident that overheating may quite conceivably occur and that various hazards are introduced. For this reason, automatic control by thermostat on electric and gas models, and by reducing valve on the steam types, are incorporated to maintain working temperatures in the liquid down to 125 degrees C. max. From the curve in Fig. 14 it is evident that there is still some solvent in the contaminated liquid when it has reached this boiling point and at which it has to be scrapped. The solvent can be reclaimed in a steam distillation plant.

A more recently introduced trichlorethylene degreasing plant not only takes care of the removal of all forms of contamination from the work, oil, grease, water, swarf and loose dirt, but also it embodies a continuous recovery of pure dry solvent, and the absorption of all vapour, in the one plant. It is the Fraser-Heller system. There is a limit to the size and space required and in general a large quantity of work needs to be handled before its installation is justified.

The Fraser-Heller system is a totally enclosed one. The following illustrations are taken from the " Mechanical World," May 29, 1942.

Fig. 15 is a diagrammatic representation of the arrangement.

Fig. 16 is a cross-section of the washing tank, showing the specially designed finned cooling pipes.

The work is loaded into the cleaning chamber, which is then closed. The work can be rotated in a barrel if its shape necessitates such treatment. Trichlorethylene vapours are injected from the upper still C into the washing tank A.

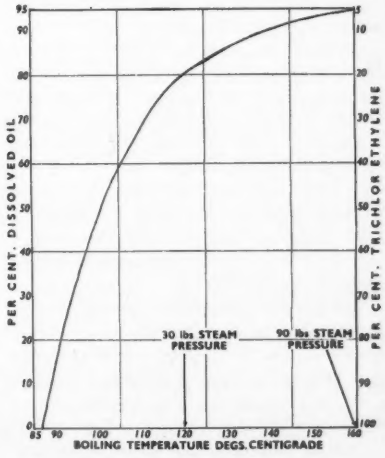
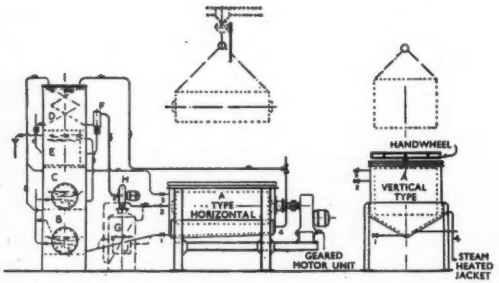
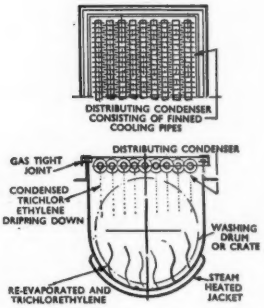

PER CENT. DISSOLVED OIL
PER CENT. TRICHLOR ETHYLENE
30 lbs STEAM PRESSURE
90 lbs STEAM PRESSURE
BOILING TEMPERATURE DEGS. CENTIGRADE
85 90 100 110 120 130 140 150 160

Fig. 14.—Effect of dissolved oil on boiling point of trichlorethylene.





Figs. 15 and 16.—Diagrammatic view of arrangement of the Fraser-Heller degreasing system, with cross-section of washing tank (right).

Condensation occurs on the cold work, which rapidly rises to the boiling temperature of the trichlorethylene. Condensation upon the work then ceases, but continues on the cooling coils, from which it rains down, giving further cleaning. Re-evaporation of solvent from the bottom of the tank occurs, oil, of course, remaining behind. The process is allowed to continue for 2 to 3 mins. The liquid residue is drained to still B. The gaseous vapours and air are withdrawn with the circulating fan H through the cooler D and air separator F. Condensed trichlorethylene from the cooler flows via the water separator E, and the air is circulated back through the washing tank A, the circulation being continued till the latter is free from vapours. A sight glass below F enables progress to be followed visually. The residues in B are continuously steam distilled via D and E to C. The outgoing air can be passed through activated charcoal for absorbing final traces of solvent. At the close of the cycle the work tank can be opened and the load removed.

For general purposes cleaning, the following summary of preferred solvents can be made for the various plastics:—

(1) Thermo-setting products, phenolic resin laminates and moulded products, phenolic cast resins, amino resin laminates and mouldings.
Trichlorethylene, using a hot degreasing plant; medium coal tar solvent naphtha or light petroleum benzine in a cold immersion plant.

(2) Nitrocellulose and cellulose acetate products, medium coal tar solvent naphtha or light petroleum benzine in a cold immersion plant.

(3) Ethyl cellulose products.
Light petroleum benzine.

(4) Polystyrene, polythene and polyvinyl chloride products.
Industrial methylated spirit in an immersion plant.

(5) Methyl methacrylate products.
Medium coal tar solvent naphtha in an immersion plant.

(6) Casein products.
Medium coal tar solvent naphtha in an immersion plant.

(7) Hard rubbers (ebonite and loaded ebonites).
Medium coal tar solvent naphtha in an immersion plant.

Many of the solvents discussed can be purchased to official specifications of the British standard or D.T.D. series. Alternatively, they may be covered by customer's own specifications. Factors to cover included items such as composition, acidity, residue, boiling point and evaporation characteristics. Suggestions along these lines are given below. Particular characteristics can, however, be modified to suit user's requirements.

Medium Coal Tar Solvent Naphtha

Composition: To consist entirely of coal tar hydrocarbons, neutral in reaction,

free from water, dirt, sediment, or other extraneous matter, and to be clear and colourless.

Residue upon Evaporation: To be 0.03 per cent. max.

Boiling Range: Volume distilling between 110 and 150 degrees C. to 90 per cent. min.

Evaporation Characteristics: To be within the limits shown in Fig. 17.

Specific Gravity: To be 0.855 $\pm$ 1 per cent. at 15.5 degrees C.

Light Benzine

Composition: To consist entirely of petroleum hydrocarbons, neutral in reaction, free from water, dirt, sediment or other extraneous matter, and to be clear colourless.

Residue upon Evaporation: To be 0.01 per cent. max.

Boiling Range: Volume distilling between 80 and 110 degrees C. to be 80 per cent. min., with 10 per cent. max. below 80 degrees C. and 10 per cent. max. above 110 degrees C.

Evaporation Characteristics: To be within the limits shown in Fig. 18.

Specific Gravity: To be 0.740 $\pm$ 1 per cent. at 15.5 degrees C.

White Spirit

Composition: To consist entirely of petroleum hydrocarbons, neutral in reaction, free from water, dirt, sediment or other extraneous matter, and to be clear colourless.

Residue upon Evaporation: To be 0.01 per cent. max.

Boiling Range: Volume distilling between 140 and 180 degrees C. to be 90 per cent. min.

Evaporation Characteristics: To be within the limits shown in Fig. 19.

Specific Gravity: To be 0.795 $\pm$ 1 per cent. at 15.5 degrees C.

Cellulose Lacquer Thinnings

Composition: To consist of 25 to 35 per cent. of ester solvent for nitrocellulose, remainder to be coal tar hydrocarbons. To be neutral in reaction, free from water, dirt, sediment or other extraneous matter, and to be clear colourless.

Residue upon Evaporation: To be 0.01 per cent. max.

Evaporation Characteristics: To be within the limits shown in Fig. 20.

Amyl Acetate

Composition: To be clear colourless, free from dirt and suspended matter.

Ester Value: Calculated as amyl acetate, to be min. 95 per cent. by weight.

Acid Value: Calculated as acetic acid, to be 0.03 per cent. max.

Residue on Evaporation: To be 0.02 per cent. max.

Specific Gravity: To be 0.870 $\pm$ .1 per cent. at 15.5 degrees C.

Acetone

Composition: To be clear colourless, free from dirt and suspended matter, purity to be minimum 98 per cent. acetone.

Acid Value: Calculated as acetic acid, to be 0.005 per cent. max.

Residue on Evaporation: To be 0.005 per cent. max.

Boiling Point: To be 56.0 degrees C. min., 50.0 degrees C. max.

Specific Gravity: To be 0.786 to 0.800 at 15.5 degrees C.

Carbon Tetrachloride

Composition: To be clear colourless, free from dirt, suspended matter and water; and to be neutral in reaction.

Residue on Evaporation: To be 0.005 per cent. max.

Acid Value: Expressed as hydrochloric acid, to be 0.0010 per cent. max.

Boiling Point: To be 75 to 77 degrees C.

Specific Gravity: To be 1.600 to 1.620 at 15.5 degrees C.

Trichlorethylene

Composition: To be trichlorethylene with suitable stabilizer. To be clear colourless, or faintly yellow, free from dirt, suspended matter or water.

Residue on Evaporation: To be 0.005 per cent. max.

Boiling Point: To be 86 degrees to 87 degrees C.

Specific Gravity: To be 1.460 to 1.470 at 15.5 degrees C.

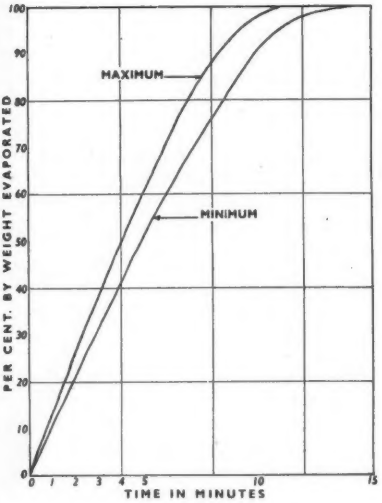


Fig. 17.—Medium coal tar naphtha method of specifying rate of evaporation.

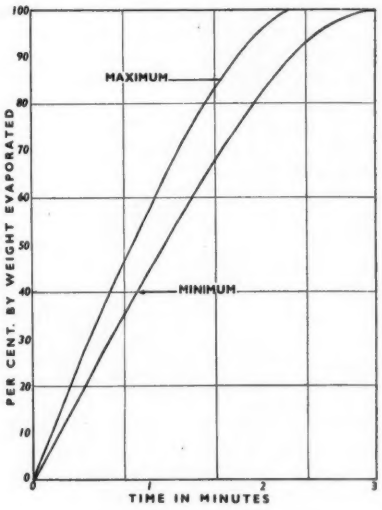


Fig. 18.—Light petroleum benzine method of specifying rate of evaporation.

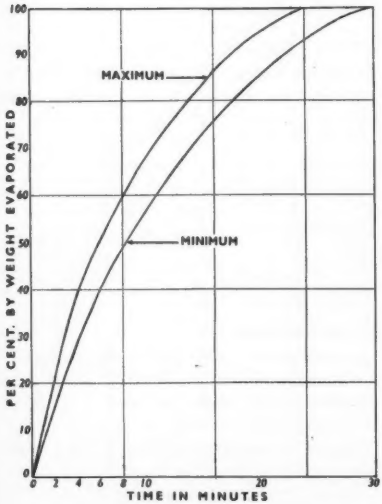


Fig. 19.—White spirit method of specifying rate of evaporation.

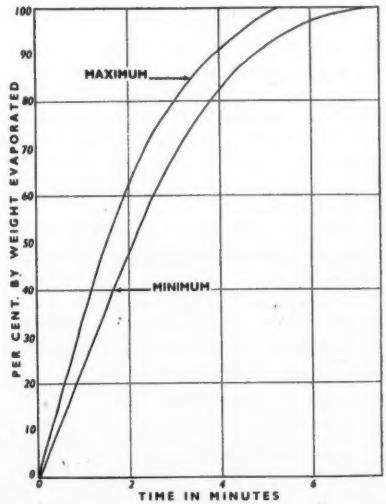


Fig. 20.—Cellulose thinners method of specifying rate of evaporation.

Acid Value: Expressed as hydrochloric acid, to be 0.005 per cent. max.

Effectiveness of Stabilizer: Exposure to bright light (sun or artificial) for seven days at room temperature, acidity not to increase beyond the specified maximum.

Industrial Methylated Spirit

Composition: To be ethyl alcohol denatured with wood spirit and containing water to the extent permitted by the proof strength value specified.

Acid Value: Calculated as acetic acid, to be 0.003 per cent. max.

Residue on Evaporation: To be 0.005 per cent. max.

Specific Gravity at 15.5 degrees C.: Maxima for respective proof strengths at 15.5 degrees C. as under:—

64 OP	... ...	0.821
68 OP	... ...	0.812
74 OP	... ...	0.798

Proof Strength: Not to be more than 0.3 degrees below the specified proof value.

These solvents are normally all supplied in metal containers, which are usually steel tin-lined, but special supplies can be obtained in glass, if so desired.

In conclusion, it is reiterated that before deciding on the type of cleanse one must bear in mind the compositional and physical nature of the plastic, the nature of the contamination, and the purpose for which the cleaning is required. Many plastics are more or less absorbent, and many are soluble in a range of solvents and in mixed solvents. Indiscriminate cleaning is therefore not practicable, and when there is any doubt tests should always be made or trials conducted. When purchasing trichlorethylene plant, arrangements can always be made with suppliers for trials to be carried out on the work concerned in order to ensure that cleaning can be achieved in a time period and at a temperature such that no damage occurs by absorption, swelling, cracking or distortion.

PLASTICS IN SOUTH AFRICA

By W. L. Speight

The possibility of developing a plastics industry in South Africa has engaged the attention of many people for some time. In an address to the Chemical, Metallurgical and Mining Society, in Johannesburg, Dr. P. N. Lategan dealt with plastics and their application, with South Africa's position for turning them to advantage. In the past 15 years a large number of synthetic plastics have been built up from very simple chemicals, mostly by-products of the coal and petroleum industries. Semi-synthetic plastics were derived from cotton, wood and milk. The needs of the war have telescoped into months the research that would have taken years to accomplish. The "ideal plastic" was colourless, lustrous, hard, tough, strong, flexible, adhesive, with suitable solubility and softening point, high electric insulation power, light, stable, non-inflammable, waterproof, chemically resistant and cheap. No one plastic combined all these properties. Plastics with particular properties were selected for particular applications. South Africa was in a fortunate position. "Ammonia, sodium hydroscide, nitric acid, hydrocyanic acid and acetylene are, or can be, produced in this country at costs which compare favourably with those in countries overseas. Phenol, benzene and other chemicals can be produced economically from coal tar, which is available in large quantities in the Union. The only essential chemical lacking is formaldehyde, which is usually obtained from methyl alcohol. I am confident, though, that the day is not far distant when we shall have in this country a synthetic oil plant of the Fischer-Tropsch type, variations of which could produce from coal via gas not only oil, but other basic chemicals such as methyl alcohol." Enough filters could be produced in the Union to meet the needs of a plastics industry of any size. Simple pigments could be made readily available. The position regarding solvents was not quite so favourable, but alcohol, and perhaps glycerine, could be produced in large quantities from molasses, a by-product of the Natal sugar industry. Most of the plasticizers required by a local plastics industry would have to be imported. The plastics industry in South Africa at present was still very much in the infancy stage. So far it was confined to the moulding of simple articles from imported powders.

SOME THEORETICAL and PRACTICAL ASPECTS of POLYSTYRENE

By William S. Penn, B.Sc.

POLYSTYRENE as a plastic is becoming increasingly important in the world to-day. With the advent of the electronics and the synthetic rubber industries, enormous amounts are now being demanded and produced. The development of polystyrene, one of our oldest plastics, was held up because of cost, but this is rapidly being reduced, and because of the present large-scale production it will be increasingly so after the war.

Polystyrene is unsurpassed as an electrical insulating medium, and as the disadvantage of heat instability is being solved, at least to a certain degree, its use in this direction is unlimited. Before explaining in any detail, however, the modern developments of the application of polystyrene, it would be advantageous to discuss recent results on the structure of the material, which have an important bearing on the industrial applications. The conventional ideas about polystyrene being a straight chain thermoplastic are now considerably modified, especially with respect to the products formed at high temperatures. This must be cleared up, therefore, before the implications of possible future uses can be satisfactorily understood.

Structure

There is general agreement on the mechanism of chain initiation and chain propagation, and as this has been explained many times before it would be out of place to discuss it here. The two other main aspects of polymerization, however—chain termination and branching—are of special significance in polystyrene, and have received a great amount of attention from many workers. Both of these mechanisms are of great importance industrially, especially the one on branching, and they will be discussed here in some detail.

Chain Termination

Chain termination, although the least important, will be studied first, as it has a very great bearing on branching. There are several main mechanisms by which chain termination can take place, and these may be summarized as follows:—

(1) Migration of a hydrogen atom[1] from one chain to another, to form monovalent radicals containing methyl groups and capable of terminating reactions. Formula (1) below.

(2) Joining of two $-(C_6H_5)C=CH_2$ radicals formed in (1) to produce cyclization at the end. Formula (2).

(3) Migration of a hydrogen atom from one end of a chain to another. Formula (3).

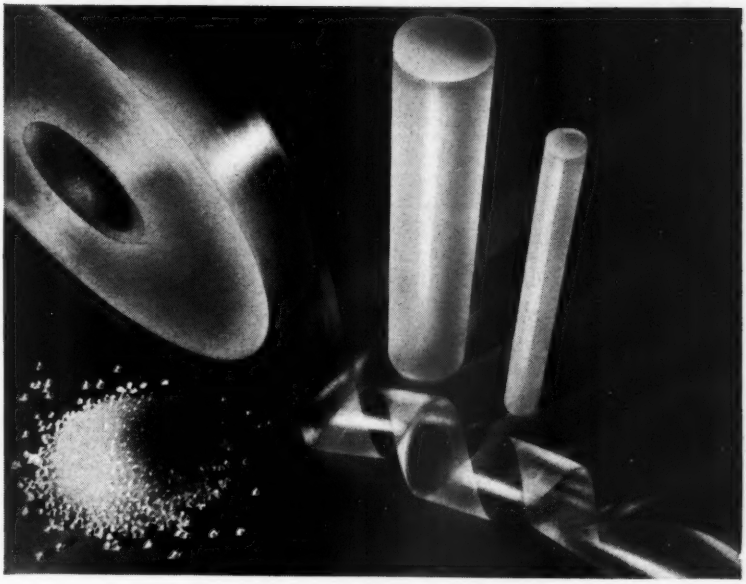
(4) Joining of ends for cyclization and

(5) Joining of free valencies with foreign molecules.

(1) $-C_6H_5CH-CH_2- \; + \; -CH_2(C_6H_5).CH- \longrightarrow$
$-(C_6H_5).C=CH_2 \; + \; CH_3-(C_6H_5).CH-$

(2) $-(C_6H_5)\underset{|}{C}-CH_2- \; + \; CH_2=(C_6H_5)CH- \longrightarrow -(C_6H_5)\underset{|}{C}-\underset{|}{CH_2}$
$H_2C-CH(C_6H_5)$

3) $C_6H_5.\underset{|}{CH}-CH_2- \; + \; C_6H_5CH=CH_2 \longrightarrow C_6H_5CH_2-CH_2-CH=CHC_6H_5$



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No. 4 can be rejected at once as being very improbable. If a compound with such a large ring were formed it would be quite stable, but the chances of it forming are extremely remote, and this possibility will not be entertained any further.

Discussion of Possible Methods

1. This seems to be quite a promising hypothesis, but it has been disproved.[2] Infra red analysis shows that there are no CH_3 groups in polystyrene, which is, of course, required by the theory. This is contrary to the concepts of Kropa and Barnes,[3] who are very much in favour of it, but evidence definitely points to it not being so.

2. It is quite possible that this is one of the mechanisms of chain termination. Some evidence,[4] although not very strong, does point to the fact that any terminal double bonds disappear on polymerization, although this is easily explained by the branching phenomena, as will be shown later.

3. It seems probable that this method is the most likely one, the migration of a hydrogen atom along a chain. There has been evidence against this, but on close examination it is shown to be positive, not negative. It is, in the first instance, the same as the reason in paragraph 2 and is because no frequencies corresponding to a double bond were found on examination of Raman Spectra of polystyrene.[4] As the migration of a hydrogen atom should take place in this reaction, experiments were conducted[5] in the presence of heavy water and alcohol. No appreciable exchange of hydrogen and deuterium between styrene and water, and water and styrene took place. It appears, therefore, that no hydrogen transfer takes place, but it must be remembered that only very minute amounts of hydrogen are involved.

On the other hand, it is concluded from the slight but definite increase of the dipole moment[6] that the double bond is maintained during polymerization. It is also interesting to note that during the inhibition of polymerization by the employment of selenium,[7] hydrogen selenide is evolved. The theory of hydrogen migration is made more creditable by the fact that it is postulated[8] that certain solvents reduce the molecular weight of polymerized styrene, because of the transfer of hydrogen or chlorine atoms to the chain.

To clear up the point conclusively, Mizushima, Morino and Inoue[9] made intensity measurements of Raman lines of polystyrenes of a lower degree of polymerization than those examined by this method before. The intensity of the band of the double bond gradually disappeared as the degree of polymerization became greater. This was to be expected in view of the fact that as the degree of polymerization increased, the residual double bonds would be used up for branching, apart from the fact that the chains became very long indeed and the bond could only show up to a very slight degree. For a polymer of molecular weight 1150, the intensity of the line 1602 was found to be five times that of 1634. For the monomer the latter was twice as strong as the former, assuming that the intensity of these two lines is proportional to the number of ethylene bonds and benzene nuclei.

4. This has already been mentioned.

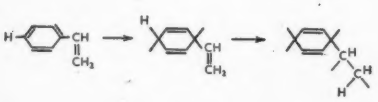
5. When we are dealing with pure styrene this particular problem does not arise, of course. This is not often the case, however, and many instances have been observed when catalysts and impurities form a part of the reaction chain. For instance, p. bromo benzene diazonium hydroxide catalyses styrene polymerization, and the presence of p. bromo-phenyl fragments of the catalyst in the chain suggest that the catalyst dissociates into free radicals. The same applies to many other substances.

Branching

We are now in a position to discuss branching, which, until comparatively recently, was unsuspected in polystyrene. The conventional formula for polystyrene

shows it to be a straight chain thermoplastic molecule, with no possibility of branching. It might be rather puzzling to see how this happens, and there are two main possibilities.

Staudinger[10] considers that it takes place by a transformation of the benzene ring into the quinoid form as shown below.



By this means extensive branching could and does take place. Evidence has been published to prove this, although the fact that the compounds so produced are never coloured tends to point away from it. It should be noted, however, that when exposed to ultra-violet radiation polystyrene gives a strong bluish tint.

According to Flory[11] the theory of the formation of branches through the growing together of chains seems more probable. Either two activated molecules are capable of reacting with one another in such a manner that only one double bond becomes saturated and the other carries on the growth, or the deactivated polymer still contains a double bond through which it may be built into a growing molecule, thus with the formation of a side chain. The truth of the matter is that possibly both of these reactions take place at the same time.

The fact must also be kept in mind of the possibility of the presence in the styrene of divinyl benzene as an impurity, formed during the manufacture of the styrene monomer. It only requires a very small percentage of this compound to cause extensive branching and therefore its influence must not be neglected.

Whatever the cause, however, the phenomenon is most important, and to illustrate it more vividly some figures will be given. It was observed[12] that the polystyrenes produced by high temperature polymerization were less viscous than those produced at low temperatures. This is due to chain branching. The higher the temperature the more branching takes place, and this is quite a regular rule. Table 1 gives figures to illustrate this point.[13]

Table 1.

Temperature of polymerization °C.	Degree of branching	Average chain length of main chain
20	1.5	2,600
60	2.3	2,000
100	3.15	1,200
132	3.5	550
220	4.3	350

This has been worked out in greater detail for each particular temperature, to show the actual complexity of the reaction. The temperature at 132 degrees C. may be taken as a convenient point for discussion. If we have a straight chain of 100 monostyrenes, we have a main branching position after every 20 monomers in the chain. Thus we have five branching positions and ten branches of the first order. These branches have an average chain length of 7.5 monomers and a total polymerization degree (together with all the branches of higher order which they bear) of 25.5. Therefore they have, on the average, three more side branches. The implications of this branching will be discussed later in the industrial applications, especially in connection with spraying.

To round off this section on structure, one or two important points on the synthesis of polystyrene can be mentioned to some advantage.

The early observations of Staudinger[1] indicated that the polystyrene possessed a regular head-tail structure. Other people did not agree with this[14] and preferred a head-head tail-tail structure. These observations did not take branching into account and therefore cannot be treated with any great finality. The point may possibly be cleared up by the fact that when various polystyrenes were examined[4] they yielded Raman Spectra rich in lines and independent of molecular weight. From this and from the constancy of the enumerated frequencies

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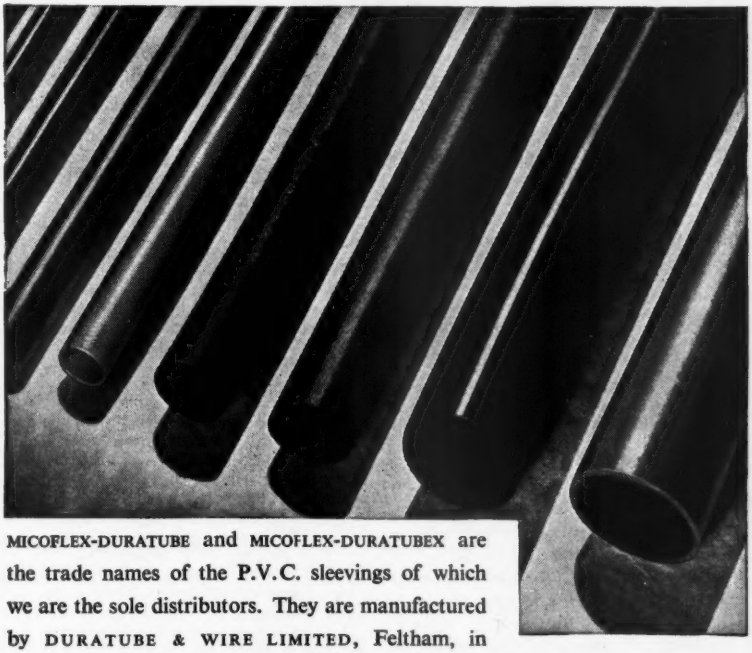

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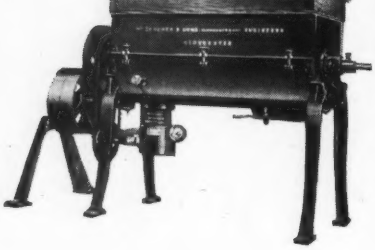

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upon passing into the dissolved state, one may conclude that any great molecular distortion is absent in polystyrene. This means, as has been shown, that the branching which does take place is quite regular.

Concerning the actual polymerization process itself, care must be taken in that a dimer is not formed. Polymerization of styrene in the gaseous stage,[15] especially at high temperatures, usually produces dimers. The catalysed polymerization of methyl styrene with concentrated sulphuric acid[16] gives a dimer, a cyclized molecule, diphenyl dimethyl cyclobutane. In this connection it is interesting to note that the polymerization of the α methyl styrene at low pressures gives an open chain dimer, whilst the application of high pressures is then sufficient to close it.

In view of the important electrical properties of polystyrene it is very interesting to observe the effects of electrical fields on the polymerization of styrene. A.C. and D.C. currents have no action on a solution of styrene in toluene,[17] but pure styrene reacts to electric fields in two ways: (a) active nuclei are formed at a definite critical voltage (47 kv./mm.), and therefore it acts as a catalyst; (b) further growth of nuclei is increasingly impeded by rising field voltage. Whilst discussing active nuclei, an interesting claim was made by R. C. Houtz and H. Adkins,[18] who said that precipitated and dried polystyrene preserves its capacity to add further quantities of styrene to itself.

In conclusion of the discussion on structure two little-known facts may be mentioned. This is some information on depolymerization as opposed to the above process of polymerization. The first is that polystyrene may be depolymerized by the action of ultrasonic waves[19]—something which I feel will throw important light on the structure of the polymer. The second point concerns the three dimensional structure built up by copolymerizing styrene with divinyl benzene.[20] This is insoluble and comparatively infusible up to certain temperatures, but depolymerization is complete at 400-500 degrees C. This shows that the styrene linkages are not too strong and throws immediate light on the ultimate heat resistivity of polystyrene plastics. This will be discussed further, however, under the industrial applications of polystyrene.

Industrial Applications of Polystyrene

By far the most important use of styrene at the moment is, of course, as a copolymer with butadiene to make GR-S, the general purpose synthetic rubber. As a plastic, however, its most important use is as an electrical insulating medium especially for high-frequency work, although, as will be mentioned later, its value in other directions is rapidly being realized. The following section is not an attempt to summarize the well-known industrial uses of polystyrene, as this has often been done before. Rather little-known facts, which may later be of some great significance, are discussed in an effort to show the potentialities of the material.

Electrical

We have already seen in the above section how electrical influences affect the polymerization of styrene. This may seem rather strange as polystyrene is pre-eminent as an electrical insulator in high-frequency work. Even more strange than this, however, is a fact discovered by two German physicists[21] concerning the permeability of the plastic. Although the absorption of water by polystyrene is exceedingly small, its permeability is rather large. This diffusion of water through polystyrene (and the majority of high polymers) gives rise to small currents. This shows the importance of keeping polystyrene dry, because the maximum value of the current reached is higher the larger the permeability.

Two detrimental points in the use of polystyrene as an electrical insulating medium are its low softening point and inflammability. A material which, when mixed with the plastic, overcomes this to

a great degree is chlorinated diphenyl.[22] The compounded material is called Styramic and it is very useful, although it is not recommended that it be used for long periods at high temperatures. Another method of improving on the low softening point is by heating the ordinary polystyrene at reasonably high temperatures (180 degrees C.) and under pressure, for long periods. The resulting improvement may be ascribed to branching, and some cross linking.

One final fact may be mentioned in connection with the electrical properties of polystyrene. This concerns the magnetic susceptibility[23] of the material. It is very high and this is regarded as being due to the disappearance of the double bonds in the polymerization process and to its anisotropy.

Properties in Solution

The properties of polystyrene in solution are most unpredictable. This may be put down almost entirely to the complicated branching and micelle formation which takes place. On the one hand, polystyrene, up to a molecular weight of about 98,000, is remarkably free from solvent effects.[24] Numerous solvents may be used to determine the viscosity, with no apparent discrepancies in the results. The other side of the picture is represented by the complex behaviour of comparatively dilute solutions.[25] The visual observation of solutions of polystyrene in toluene gives no indication of solidity. A 15 per cent. concentration, however, produces a solution which appears to be a moderate viscous liquid which has the rigidity of a stiff gelatin gel. A 50 per cent. solution which flows without yield point has a rigidity of about that of raw rubber.

These effects are very important from the point of view of spraying. Polystyrene possesses certain excellent properties, and although it has been very little employed for this purpose up to the present, its use as an important lacquer is forecast. The lacquers will probably be applied by spraying, and there is, therefore, a need for studying this problem. It is difficult to use polystyrene for spraying because of cobweb formation. This is due either to too great a viscosity of the solution or insufficient air pressure. The latter fault can readily be corrected, but the former is much more difficult. The obvious method is by thinning, but there is one great objection to this, the reduction of the concentration of the styrene. This means wastage of solvent and increased drying times. A method which will be applied on a much greater scale is the use of high-temperature formed polystyrenes. This means that a great amount of branching takes place, and a reduction in main chain length is caused, with a consequent decrease in viscosity for the same molecular weight. This is made possible by the apparent fact that the side chains do not affect the viscosity, it being due primarily to the main chain. When the main chain becomes shorter than the branch chains this does not apply, of course.

The flexible films of polystyrene, which are now being produced, need little mention. There is one important fact, however, which must not escape notice. A tough flexible film may be made[26] by heating a solution of styrene with not less than 5 per cent. of water. This cheap novel method may be of great interest in years to come. It is useful to note that polyfurylethylene[27] forms films which dry tack free in eight hours, harden in 24 hours and are compatible with nitrocellulose, which shows the possibilities of polystyrene and its derivatives as film producers.

The effect of milling on the viscosity of solutions of polystyrene[28] may be mentioned before closing. It is reduced considerably, and is due to the rupturing of primary valency bonds. In a milling time of 10 hours the viscosity can be reduced from a value of 2-5 poises to 1.0 poise. Further milling has little effect. It has been calculated that of the energy available for rupture most goes to the breaking up of Van der Waal forces and only a small part to the rupturing of primary valency bonds.

Solid Polystyrene

Polystyrene is a very versatile material and will lend itself to most fabricating processes. It can be decorated in many ways, and most of its inherent defects eliminated by suitable compounding, which up to the present is not practised to any great extent. This has been due to a desire not to reduce in any way the excellent electrical properties of the material. Plasticizers and other compounding ingredients are now being found, however, which do not cause this, and their use is becoming increasingly important. One of these plasticizers has already been mentioned, namely, chlorinated diphenyl, and others include diphenyl phthalate and aroclors. The diphenyl phthalate imparts a high gloss to the plastic.

Products related to polystyrenes are becoming increasingly important. All the three of o, m, and p polybromo styrenes[29] give hard, colourless, brittle and transparent products, which are approaching the highly desirable material, hard (unscratchable), transparent, colourless and light stable plastic optical glass.

In connection with these derivatives, and to save quoting the innumerable examples which exist, it would be advantageous to point out that polystyrene enters, in solution, into many chemical reactions. The phenyl group can be sulphonated and halogenated, etc., and the products so formed used in many modern industrial applications. It has been ascertained that the ortho derivatives give the greatest mechanical strength and resistance to heat, and this fact will be explored to the full.

A further way of modifying polystyrene resins is to copolymerize with substances such as maleic anhydride, which can react further, even after they have been polymerized. By this means the reactive groups in the copolymer chain can be used to confer many properties on the original resin.

Polystyrene lends itself to colouring very readily and the monomer styrene, when polymerized with fluorindenes and other dyestuffs, gives very beautifully coloured masses. The addition of 0.5 per cent. anthracene gives a violet fluorescence which does not affect the transparency of the finished product.[30]

Polystyrene is used mainly for injection moulding and no discussion would be complete without some mention of it. An important point is that injection mouldings undergo a transformation at 80-85 degrees C.[31] At temperatures below this they are tougher than those produced above. This is probably tied up in some way with the branching. The tough resins produced at these low temperatures are used in refrigerators, because they maintain their toughness, and also because of their low water absorption, dimensional stability and freedom from colour and taste.

Special precautions have to be taken in the injection moulding of polystyrene, as it is less flexible than most thermoplastics

Table 2.

Properties	Injection mouldings	Compression mouldings
Tensile strength (lb./sq. in.)	7,000	7,000
Modulus of elasticity (lb./sq. in.)	$0.4–0.55 \times 10^6$	$0.17–0.7 \times 10^6$
Izod impact (ft. lb./in. notch)	0.65–1.25	0.2–0.6
Flexural strength (lb./sq. in.)	17,500	6,000–19,000
Water absorption	None	None
Specific heat	0.32 gms./calories/°C.	0.32 gms./calories/°C.
Dielectric strength (60 cycles)	510 volts/mil.	510 volts/mil.
Power factor ($60–50 \times 10^6$ cycles)	0.0002–0.0003	0.0001–0.0004
Dielectric constant ($60–50 \times 10^6$ cycles)	2.55	2.5–2.8
Index of refraction	1.594	1.59
Moulding temperature °F.	300–500	275–350
Moulding pressure (lb./sq. in.)	3,000–30,000	300–5,000
Bulk factor	—	2.0–2.5

These figures are not of course absolute, and reasonable variations are to be expected.

and takes the details of the die very accurately. Dies without any trace of undercuts must be used, and they must have an excellent finish. Large gates and short runners yield mouldings with greater strength than those where long runners are used. High clamp pressures must be available, as it is advisable to use high ram pressures. It is worth noting also that gates and welds tend to be weak points in moulded polystyrene parts, and therefore these should be placed in such a position that they are not subjected to high stress. Table 2 compares some of the properties of injection-moulded and compression-moulded polystyrene. The differences caused by the two methods will be apparent.

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Elastic and Creep Properties of Filamentous Materials and Other High Polymers

By Herbert Leaderman, Sc.D.

DURING the past few years there have been many remarkable technical developments in the field of high polymers. These developments have consisted in the production of new materials; in the modification of existing materials; and in the finding of new applications for existing materials. The important role played by synthetic high polymeric materials in the war effort and elsewhere is due in a large measure to their valuable mechanical and electrical properties. In an effort to understand better the nature of these properties, and how they are related to the chemical constitution, much work has been done on the physics of high polymers.

The present work is concerned with a study of a phenomenon—delayed elasticity—which is observed in most high polymers, as well as in other materials. The second part of the book gives an account of experiments that have been carried out by the author at the Massachusetts Institute of Technology, under the auspices of the Textile Foundation, on the creep and creep recovery behaviour of rayon, nylon, and silk filaments. The experimental results are interpreted in terms of the structure of these materials, and conclusions are drawn concerning the mechanism of elastic and plastic deformation of textile filaments.

The first part of the book deals with similar work that has been carried out with other high polymers, and contains a critical discussion of relevant theories and of previous experimental work on delayed elastic behaviour in other materials, such as glass. This book, in presenting some of the current concepts concerning the structure and mechanical behaviour of filaments should be of value to the textile industry.

The book may be obtained from the Textile Foundation, National Bureau of Standards, Washington, 25, D.C., price $2.00 per copy, post paid.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

I.P.I. (WESTERN SECTION). The summer meeting of the Western Section of the Institute of the Plastics Industry took place in Stroud on July 21, and consisted in a joint visit to the works of T. H. and J. Daniels, Ltd., and Erinoid, Ltd.

A good time was had by one and all, not only because of the lunch held at Amberley Ridge Hotel, but also because it was presided over by the amiable Mr. A. A. Heath, the chairman of the Section, who proposed the toast to the guests. Mr. Graesser Thomas, the new chairman of the British Plastics Federation, replied.

The visitors, who were later shown round the works in small groups, included the following:—F. A. Cook, chairman of I.P.I.; C. S. Dingley, vice-chairman; H. V. Potter, who gave the address at the inaugural meeting of the Western Section a few months ago; H. H. Lusty, chairman of the London Section; A. H. Wilson, chairman of the Midlands Section; and Dr. H. Barron, chairman of the Southern Section.

THOMAS DE LA RUE AND CO.—In his statement at the 47th Ordinary General Meeting, the chairman, Mr. B. C. Westall, included a generous tribute to the work of De La Rue Plastics, Ltd., to the energetic drive of its managing director, Mr. H. P. Bridge and commented on the high level of plastics production. He also made the following significant remarks which will be welcomed by scientists throughout the country:—"The policy of enlarging the Research and Development Departments has been continued. During the war our activities have been restricted to finding new applications of plastics to war purposes. Even more could have been done had we been able to obtain sufficient technical staff with the necessary qualifications for carrying out research. It is to be hoped that the Government will bear in mind the desirability of making available for industrial concerns at the earliest moment possible experts in chemistry and engineering, so that the groundwork for industrial expansion may be prepared in good time. In a comparatively new industry such as plastics research and development are even more important than in the case of the older-established industries. In our own case the Board of De La Rue Plastics has projects in view which await the engagement of technicians."

HOOVER, LTD.—Two very interesting events were celebrated at the Hoover factory, Perivale, on July 14—the incorporation of Hoover, Ltd., 25 years ago, and the completion of 25 years' service with the company by Mr. C. B. Colston, chairman and joint managing director. To mark the occasion, the members of the organization presented Mr. Colston with an oil painting of his home, "The Danes," at Penn, Buckinghamshire, by Mr. Charles Cundall, R.A. To most people, of course, the name of Hoover is associated with electric cleaners, but during the war their manufacture has ceased and the whole resources of the company have been concentrated on war work.

PRODUCTION BULLETIN.—The July, 1944, issue of this valuable bulletin published by the Ministry of Labour and the Ministry of Production contains some valuable articles on "Assembling Precision Units on a Stop-and-go Conveyor System," "Ventilating a Drop Forging Shop," "Records of Absenteeism" and the reproduction of an excellent lecture by Dr. W. G. Hiscock, of the Ministry of Supply, on "Maintenance of Discipline—the Modern Approach." Finally, for those who can sympathize in a practical way with those working under physical handicaps, there is an illustrated note on "Deaf Workers in Industry."

Testing Plastics with Infra Red Rays

If plates of Mipolam (polyvinyl chloride) are examined by transmitted light of various wave lengths, it is found that ultra violet light as well as ultra soft X-rays are almost completely absorbed, whilst infra red illumination shows up many structural details and can thus be used to examine welds in this material. It appears likely that this new method will prove of value not only in routine testing but also in general research on plastic materials.—(F. Steuber, "Schiff und Werft," Vol. 45/25, Nos. 5/6, March, 1944, p. 68.)

Planned Mould Maintenance Service Aids Economical Production

Part III

(Continued from p. 344, July issue)

By W. M. HALLIDAY

Considering some simple and useful mould design and constructional features which promote increased accuracy, prolonged wear, and correspondingly reduced maintenance oversight or repair activities

A Semi-positive Compression Mould

IN Fig. 3 is shown a full sectioned view of a semi-positive type of compression mould, which may be regarded as a representative specimen of this kind of tool. It will be noted this design incorporates a number of core members for forming holes in the central web of the moulded article.

Several very important objections appertain to this design and construction from a maintenance angle, which, whilst undoubtedly of an inexpensive kind, and one easily produced as far as initial outlay is concerned, may give rise to a considerable amount of maintenance attention to retain it in smooth and sound working condition.

Dowels. — The first unsatisfactory feature to be noticed is that of the method of dowelling and the type employed. The dowels (C) shown are very commonly employed for securing alignment of the top and bottom die blocks. The portion of dowel secured in the web of the top die block is reduced in diameter so as to form a small step. It is made a drive-in fit and then its top end is riveted over to fit the small countersunk recess in top die block.

The disadvantages chiefly to be observed are as follow:—

(1) Unless the reduced portion fitting in top die block is made a very tight fit there will be danger of pulling out as the peened over end will be insufficient to withstand great dragging pressures.

(2) By reducing the shank portion of the dowel it is correspondingly weakened.

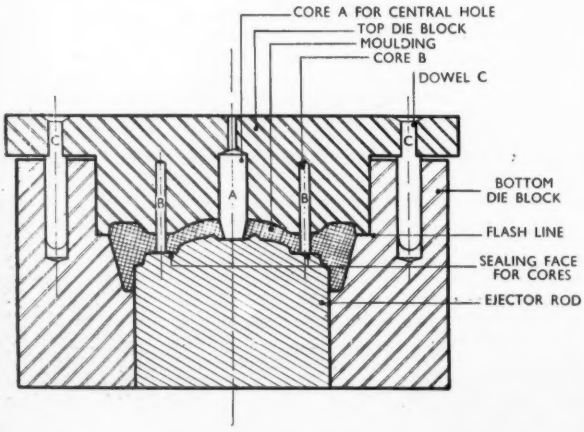

Fig. 3.—Semi-positive type of compression mould.

(3) The reduction in diameter is so small that a substantial or adequate step portion cannot be secured against which the dowel may be squared up when riveting occurs.

In actual service it will be found that the constant frictional contact of dowel within bottom die block will in time tend to loosen the riveted head, thus allowing dowel to work loose and all aligning facilities to be lost.

Core Pin Construction

The second undesirable feature to be considered is that of the three core pin members attached to the top die block as shown at A and B.

These three cores are so arranged that their end faces are brought to bear against the top surface of the ejector rod. From this it will be gathered that the three holes have to be cored clean through the central web of the moulding. This is likely to lead to several troubles, chief of which are the following:—

If the ejector rod is not positioned accurately so as to bear against core pins as a result, say, of dirt between lower edge of bottom die block and press platen, or because of a slight misalignment of platen itself, a slight gap will be left between the ends of core pins and ejector rod, which, of course, will be filled with a fin of material in the finished moulding.

Secondly, if the ejector rod is inadvertently raised and held in too high a position damage may be done to the ends of core pins, especially those of relatively small diameter. Such damage may consist of deflected or bent pins, bruised heads, or their displacement in top die block. In addition a faulty moulding will also result.

Thirdly, the only provision for securing these core members into place in top die block is by the degree of tightness of their fit in socket holes. The degree of tightness may be subject to some variation under the influence of contraction and expansion arising from varying mould temperatures. Thus if the mould is allowed to reach too high a temperature the die block may expand slightly more than the core, allowing the latter part to loosen.

Fourthly, no provision is made for adjustment of the core pin setting. Should circumstances arise which require that the core pins be depressed or advanced a small amount, this may prove a difficult operation, because the pins will have to be removed and a small amount of material taken off their rear end faces to ensure the appropriate amount of alteration. Removal of the pins for such an adaptation will almost surely mean that they cannot be driven back again with the same tightness. Again, it is rather a cut and try method since the maintenance engineer has no means of determining the amount the core pin will alter as a result of the removal of a specified thickness of material.

Fifthly, another important consideration to be borne in mind, as likely to cause trouble, is that if for some reason or other the core pins are disturbed in their setting by a slight withdrawal from top block, this will mean that the sealing faces of the two blocks shown at the indicated flash line will be held slightly apart. In such circumstances extra flash at this point will result. In addition, and this more serious for the maintenance man, the bulk of the pressure imposed on the mould will become concentrated upon the core members and not entirely on the sealing lands. Such pressure may cause serious damage to the cores if they are prevented from being pushed back again.

Ejector Rod.—In connection with this essential mould member, all the operating and constructional disadvantages noted in the case of the ejector in the design in Fig. 1 relate also to this present instance.

A considerably improved design form is illustrated in Fig. 4, and here again the various features are dealt with in identical order, as in the case of design shown in Fig. 3.

Dowels.—Still another form of dowel is shown at C and D in Fig. 4, this type being much superior to that used in Fig. 3. As will be appreciated, they consist of a shouldered dowel riveted into position to the web of top die block. The shoulder

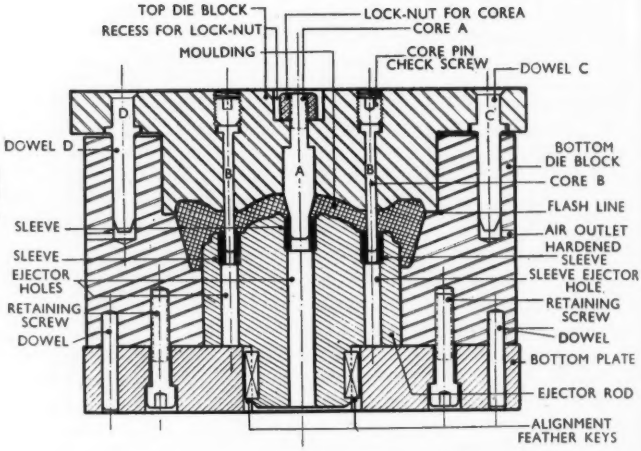

Fig. 4.—Improved design on mould shown in Fig. 3.

should be of ample proportions as regards diameter and thickness relative to the shank diameter of dowel. Thus the outside diameter of shoulder should be not less than twice that of dowel shank, whilst in thickness it should be not less than one-third shank diameter. The top die block web is counterbored on its underside around hole to house this shoulder. The diameter of hole in top block is the same as that in bottom block, which factor makes for easier drilling. The shoulder portion affords ample abutment for ensuring that the dowel is held square when being riveted.

Instead of a semi-spherical lead a slow tapered one is provided.

Cores

Several desirable and useful modifications are shown in respect of the three cores A and B.

First, instead of each of these being arranged so as to bear down upon the top face of the ejector rod, as shown in Fig. 3, this latter member is drilled appropriately so that each of the cores may be extended in amount projecting from top die block sufficient to allow them to be passed into the said holes in rod. Each hole in the ejector rod is provided with a hardened and ground steel sleeve driven tightly into position, so that its top end face is brought dead in line with the end of ejector rod, which portion normally forms the inner recess of the moulded article.

Each of the hardened sleeves, it will be noted, bears against a small step formed by the slightly smaller-size hole, which continues for the remainder of the length of the ejector rod. This ensures against the sleeves being forced within the ejector rod as a result of working conditions or compression forces, so leaving a gap at top end, which would be filled with material in the shape of a raised boss on the bottom inside surface of the finished moulding.

These sleeves will be easily replaceable when worn, they being removed simply by forcing out by means of a small punch inserted into bottom end of holes up ejector rod.

It would be possible to omit the use of such sleeves by passing the cores directly into plain holes in the ejector rod, but the little extra time and money needed would be well repaid if sleeves are introduced, as the task of correcting wear can then be accomplished with greater ease and a minimum of trouble.

As will be understood where sleeves are not used, any wear calling for correction might involve costly operations, such as

the softening of the ejector rod, redrilling the holes to a larger diameter, and the fitment of sleeves to restore them to original size. Great care would have to be taken during such machining operations lest the act of opening out the worn holes leads to a departure from the correct hole centre, in which event difficulty would subsequently be experienced in aligning up the core pin with the bottom die block and ejector rod therein.

Secondly, each core pin (B) at the side of moulded article is provided with an enlarged head portion, which is housed with a suitably counterbored recess in top edge of top die block. The extreme top portion of this recess is threaded to receive a small checking screw, which is used so as to bear down upon the head of core pin, thus preventing the latter from being moved backwards out of die block.

By this simple provision a very secure locking of each core pin is obtained, whilst should adjustments be necessary the core pins may readily be withdrawn by the removal of the check screw. Slight amounts may then be removed from the underside of the core-pin head, if it is wished to secure additional projection of pin through die block, whilst thin shim-stock washers may be inserted underneath the head and between the bottom of recess in block if the pin has to be moved farther within the die block for any reason.

In the case of the larger central core pin (A), positive locking means and easy adjustment provisions are also arranged. It will be noticed that the plain shank of this core normally bearing in top die block is made of two diameters, and the hole in block similarly formed. The extreme end portion of the smallest diameter shank of core is externally threaded to take the steel lock-nut as shown. This nut passes down into a counterbored portion of hole in block. This recess is deep enough to allow the lock-nut to pass completely below the level of top face of block, as indicated, and large enough to admit easily a tube-type wrench, by which means the nut may be secured.

Thus a powerful locking pressure can be secured, whilst adjustments for length of projection can be made by removing material or inserting packing shims in the manner described in reference to cores B.

Ejector Rod

Since the core pins are extended to pass into the end of this rod it will be essential that this latter component be prevented from independent rotation relative to bottom tool, otherwise there would be a risk of the three holes getting somewhat out of correct alignment with the cores, which would result in these latter being fouled and badly damaged when the mould blocks were brought into the closed position.

A simple yet almost foolproof method is here illustrated whereby such dangers may be avoided. The rod it will be seen is reduced in diameter at its lower end for a distance almost equal to the thickness of the bottom plate. This concentric cylindrical shank is made a sliding fit within the ground bore of the bottom plate.

Rotation of this rod is prevented by means of the two feather keys which are fitted into shank of rod diametrically opposite. The rod and its keys should then be a smooth sliding fit in bottom plate. This keying and fitting operation should preferably be performed before the guide holes in top of ejector rod are transferred from the top die block. If this operation is deferred until rod is keyed satisfactorily the holes can be machined at the correct spacing and location without trouble.

In order to prevent the ejector rod from being inserted the wrong way round one feather key should be made slightly wider than the other, thereby limiting admission of rod to bottom plate to one way only.

The bottom plate, incidentally, is secured to the bottom die block by means of socket-head cap screws, and two plain dowels driven tightly into position. The bottom plate and lower die block are thus secured together positively and act as a single unit during operation.

By this construction it will be appreciated that the ejector rod is afforded ample and positive checking means by the step in its diameter, and that of the

hole against which it can be positioned at each assembly. The only trouble likely to arise in this connection is the accumulation of surplus plastic material, oil, or other extraneous matter on the seat portion, which, of course, would have to be closely watched by the operator.

Some wear will occur in respect of the feather keys, but their checking and renewal when occasion demands will be a straightforward operation and need necessitate no long withdrawal of the mould from production service.

Whilst the design here illustrated and described is again one of the simple portable type of flash mould embracing cores, the constructional features suggested above, as illustrated in Fig. 4, will be equally appreciable in the case of fixed moulds containing core members and the like.

Lubrication of Mould Members

So far no mention has been made of the important matter of lubrication, chiefly because the mould designs and constructions dealt with have been extremely simple, having few moving members, and moreover being of the portable type. Usually these latter kind of tools receive a clean-up and application of lubricant on essential parts after each compression stroke has been made and the finished moulding removed.

But in the case of fixed moulds, which are attached to the press platens for the whole of the production run, opportunities for cleaning and applying fresh supplies of lubricant to needed parts are often somewhat restricted. Hence provision must be made in the construction itself for ensuring that adequate access is afforded for lubricants. Means should preferably be provided, too, for the careful retention of such lubricants for reasonably long periods.

Such requirements often involve the mould designer and manufacturer in some troubles, but a little thought will be well expended as such provisions very materially affect the working condition, durability, degree of wear, and general smooth operation of the mould. Serious seizures and fractures are often prevented by judicious use of lubricants; therefore, from the point of view of maintenance, such matters should receive attention in the design stages, and constant check-up by the inspecting maintenance engineer to ensure that all essential parts of the mould are being properly fed.

A Semi-positive Fixed Mould

The next two illustrations in Figs. 5 and 6 are of a typical three-impression semi-positive fixed-type compression mould. This is rather more involved in design and construction than previous examples, and contains a number of interesting features of some importance to the maintenance engineer.

Devoting attention first to the sectioned assembled view shown in Fig. 5, which illustrates the various undesirable features, it will be specially noted that the upper portion of each cavity is contained in a separate die block. The three top die blocks are fitted into the top plate in such a manner as leaves much to be desired. The two end blocks are supported by the top plate only back and one side, the outer side in each case being finished off flush with side wall of central-extension of top plate, and in direct contact with the sides of the recess in bottom die block as shown.

This will allow a considerable rubbing and dragging pressure to be directly imposed upon the side of each die block every time the mould is opened or closed. In time such action may cause wear of the die block, or a disturbance in its position relative to the top plate. Should this occur there would be some risk of a seizure or awkward jamming of top tool on the succeeding closing of the mould members.

Such movement would also result in throwing the top half of cavity out of correct vertical line with the bottom portion contained in the bottom block.

The question of effectively remedying wear which occurs on the sides of the two end die blocks will also present some difficulty to the maintenance engineer. The inserted blocks would have to be

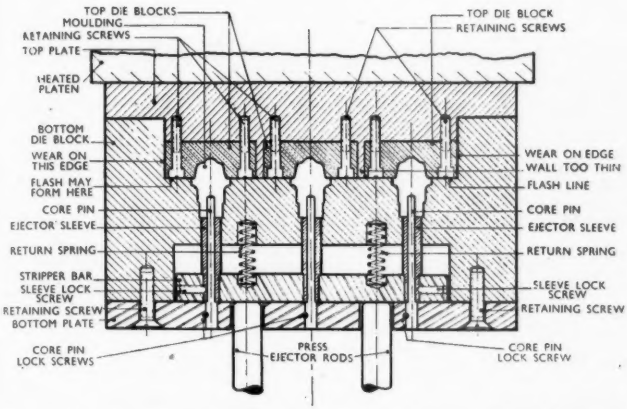

Fig. 5.—Typical three - impression semi-positive fixed type of compression mould.

removed and replaced with a new piece altogether, or the old block may be built up in some manner on its worn side.

Fixing Screws for Die Blocks

Then again, the method of locating the fixing screws in the three top die block inserts and the top plate leave much to be desired. Unless considerable care is used by the operator trouble will arise in several directions.

Ordinary type cheese-head screws are employed, as will be seen, these being screwed into tapped holes in the top plate and thus located in the three die blocks with their heads passed into counterbored recesses on the flash line. These recesses cannot be machined with such accuracy as to effect a complete seal both circumferentially and on top of the head. And as the recesses are situated near the edge of the cavity, unless caution is exercised a flash-over of surplus material may occur, this running over into any spaces or tiny gaps left around screw heads.

Should such excess material build up in such situations considerable trouble may be experienced by an operator in

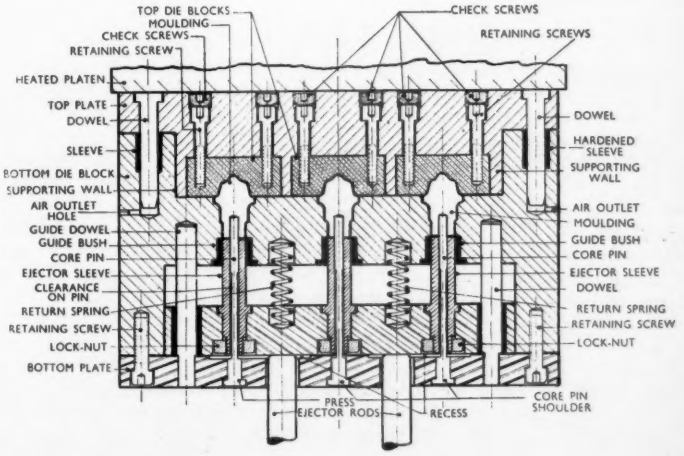

Fig. 6.—Method of overcoming faults, etc., in mould shown in Fig. 5.

removing them without either inflicting some injury to the sharp edges of the mould cavities, or else removing the mould blocks from press in order to gain better access.

Unremoved build-up at such points would render full closure of the mould increasingly difficult, with the result that the condition would tend to be aggravated and would be distinguished by additional flash on the moulded article, and increased harshness and resistance when closing or opening the mould.

Furthermore, since it is difficult to secure a very powerful lock on such screws, by reason of the necessity to use an ordinary screwdriver, the constant repetition of mould opening and closing and the resultant jar would tend to loosen the holding screws. Or again, heat variations of the mould would cause some stretch of the screws, in either case the result being a loosened die block.

Ejection Sleeves and Stripper Bar

The moulded knobs shown are provided with a moulded-in hole extending a short distance up the centre of their plain shanks. This hole in each case is formed by a core pin. Ejection of the finished knobs is accomplished by means of sleeves carried over the core pins and attached to a sliding stripper bar or plate, as shown. This, incidentally, is a very common method of ejection incorporated in a wide variety of mould designs. The construction here illustrated, however, will be characterized by several operating and maintenance snags worthy of closer attention.

First, the outside diameter of the front (upper) end of these sleeves is in each case smaller than that of the plain shank of the finished moulded knob. This will mean that on each part moulded a circular ring will be formed around its end coinciding with the outside diameter of the sleeve.

Secondly, the sleeves are affixed to the stripper bar by means of a reduction in their outside diameter at one end, this portion then being a tight press-in fit within the holes in bar. Each sleeve is further assisted towards safe retention in place by the small grub screw locked down on to a dimple machined in the side wall of each sleeve as shown.

This is a most insecure method of fastening, even though the fit between sleeve and hole in bar is extremely tight. It must be remembered that very considerable drag may be imposed on the sleeves during their operation, which might be great enough to cause a shearing of the pointed end of the grub screws and a pull out or shifting of the position of the sleeve in the bar.

Regarding the design of the stripper bar, here again some troubles are likely to develop; a little consideration will reveal this to be of a type very unlikely to result in smooth working, accuracy, or prolonged absence of wear.

It will be at once observed that the only means for guiding and aligning this stripper bar along a correct path during its stroke is that furnished by the ejection sleeves themselves. One has only to envisage one or other of the twin press-ejector rods bearing on the stripper bar slightly ahead of its companion to foresee that the stripper bar will be immediately skewed round until contact is made at its other end with the second rod.

Such a twisting movement, of course, will be immediately transmitted to the three ejecting sleeves, and from them to the three core pins housed within. The result of such twist, be it ever so slight, will tend to tighten up the movement of sleeves with their guide holes in bottom die block, as well as imposing greatly increased frictional resistance upon the core pins within, all of which will combine to render free working extremely doubtful.

Unequal pressure on press ejector rods, or a misalignment of the mould between press platens, may also produce side twisting of the stripper bar and similar results as already mentioned.

Should such a feature arise in fairly acute form the sleeves may be permanently distorted, whilst the core pins may be completely fractured at the juncture of their slightly larger shank portion fixed

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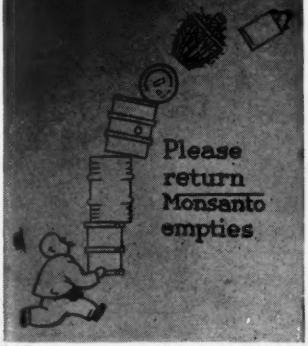

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into the bottom plate. These troubles could involve considerable time and labour on the part of the maintenance engineer.

Yet another undesirable feature worthy of careful notice concerns the method employed for returning the stripper bar and ejection sleeves when the moulded knobs have been ejected from core pins and cavities. This return movement is obtained by means of a pair of stiff compression springs interposed in suitable shallow recesses between the top face of the stripper bar and the upper face of the cutaway slot in the bottom die block.

From the writer's own experience, springs are unreliable and hence are not recommended except in those constructions where it is impossible to install a purely mechanical arrangement for securing stripper bar return. Springs are unreliable, non-positive, are liable to fatigue and loss of strength due to continued flexing, or under variations of heat such as are found in plastic moulds. More trouble may be caused by a spring which is gradually fatiguing and losing its strength than by one which fractures or collapses suddenly and brings the mould to a standstill. In the former case, each time the stripper bar requires returning to the open position the sound spring will exert more pressure on the bar than its opposite number, with the result that the bar will tend to follow a crooked line of travel, which, of course, will lead to its binding and perhaps seizing up altogether.

In this present instance the springs are located immediately in front of each press ejector rod as shown.

Core Pins

The method of fixing the core pins is not altogether satisfactory. These pins, it will be seen, are passed through a plain parallel hole in each ejection sleeve, within which they are made a free sliding fit. Their lower end portion is enlarged in diameter for a short distance and passes into suitable holes provided in the fixed bottom plate, which, in turn, is secured to the bottom edge of the lower die block. Reliance is made for their secure retention therein upon the tightness of the fit, aided by a small cross pin driven into a cross-drilled hole passing half-way through core pin and half through bottom plate.

Should the ejection sleeves bind, or become very stiff in their passage over the core pins, there is a danger that the small cross pin in the bottom plate may be sheared off and the core drawn along with the moving sleeve.

The repeated backwards and forwards travel of the sleeves over the core pins may produce a slackening of the latter, which would incur a loss of correct endwise location of the projecting end of the core pin within the cavity, and a variation in hole depth ultimately formed in the moulding.

The illustration shown in Fig. 6 indicates simple ways in which the foregoing disadvantageous features may be overcome without incurring greatly additional mould cost or complexity. The increased mould life and more reliable and trouble-free operation will outweigh the little initial extra cost needed to effect such modifications of design.

As previously, the various features will be treated in the same order as in the case of the mould shown in Fig. 5.

The Top Die Blocks

These three die blocks are each let into the bottom face of the top plate in such a manner that each block is surrounded back and both sides with a wall of metal of the top plate. This ensures that no side of the die blocks is exposed to direct frictional contact with the sides of the cavity recess in the bottom block; thus wear is eliminated, as is also all danger of such rubbing action causing a loosening of the blocks.

It is appreciated that the task of machining the top plate in this fashion so that the die blocks are each inserted in a pocket may incur some additional machining expense, but the working advantages derived will much more than offset this.

The wear will fall upon the side walls of the top plate, and, if requiring correction,

it can much more easily be accomplished than in the previous design. A little material would probably be removed from each worn side and strips of hardened steel secured thereto to bring the plate extension back to its original shape and overall width to suit the cavity recess.

The top plate is also dowelled, as shown, into the bottom die block, which feature will still further assist in reducing possible wear on the side walls of the top plate.

Incidentally, another type of dowel in common use is here shown, as this form is a decided improvement over the straight type, having a riveted overhead.

It comprises a plain cylindrical shank topped by an enlarged head suitably housed in a counterbored recess in the upper edge of the top plate. Hardened sleeves are inserted into the bottom die block as shown. Thus wear is easily corrected either by replacement of worn sleeves, or by a new dowel, or both.

Fixing Screws for Die Blocks

Here again use is made of the toughened steel socket head cap screw, but these are located in reverse direction to that shown in Fig. 5. Blind tapped holes are machined in the back of each die block, and the screws are passed in from the uppermost edge of top plate. The holes in this latter member are counterbored to suit the screw heads, allowing them to pass well below the surface, as indicated. The remaining portion of the counterbored hole is then tapped to receive the check screws, which latter bear down upon the screw heads. This is a safety measure largely, and ensures that the screw cannot jar loose as a result of vibration.

The writer has found it a good plan to afford such screw fastenings a check up every few weeks, to ascertain the degree of lock still possessed. The maintenance engineer should first remove the upper check screw, and then test by key wrench whether the main holding screw has slackened at all. When these have been finally adjusted the check screws should be retightened down on to heads of screws underneath. This will maintain the top die blocks always in a firm and secure condition, as a result of which such troubles as increased flash, due to one block loosening and becoming pushed slightly forward by reason of lodging material on back or sides, will be avoided.

Ejection Sleeves and Stripper Bar

The design and construction of these members is modified considerably in the following manner, in order to eliminate the forms of trouble in service.

First of all, the outside diameter of the ejection sleeves is made the same as that of the shank portion of mould cavity, with the exception of a few thousandths reduction to afford the sleeve free working clearance within the cavity when pushing off a finished part.

A hardened steel guide bush is located tightly into the hole immediately behind the cavity in the bottom die block, as shown by heavy black shading. These sleeves, it will be observed, are provided with a shoulder at the upper end, which is let into a recess. The top edge of the bush coincides with the end of cavity. The sleeve within the bush is adjusted and set so that when occupying the open position shown herewith its front endface is exactly in line with the top of hardened bush.

At its other end each ejection sleeve has another enlarged cylindrical shoulder, which can pass easily into a recess formed around top edge of hole in stripper bar. The remaining plain portion of sleeve is then made a drive fit within the bar, and a short, reduced threaded stalk on extreme end of sleeve allows a lock-nut to be screwed home into another recess on opposite side of stripper bar. By this means the ejection sleeve can be very powerfully locked to the bar, without fear of throwing same out of square when locked up.

The other advantages of this construction are: that the finished moulding will not have a circular mark around its endface, as in the preceding instance; the holes of bushes in bottom die block will be the ones likely to wear, or else the ends of ejector sleeves, which need not cause

trouble as these are easily replaceable, which operation, when it arises, need not involve extensive work or protracted labour requirements.

The stripper bar is made much thicker in cross section, as shown, and is provided also with two ample dowels. These dowels extend from the bottom plate, through the stripper bar and well into the body of the bottom die block. To prevent them moving endwise the portion fitted into the bottom plate is of a reduced diameter, thus leaving a step which should be slightly clear of the inner face of bottom plate when latter is clamped up. The dowel thus cannot move outwards.

In the stripper bar the two dowel holes are provided with hardened steel sleeves, which, of course, are easily renewable as demanded by circumstances.

These dowels will constrain the stripper bar to follow a correct and true path during each movement it makes, regardless of the stripping sleeves. They also serve for positioning the bottom plate correctly to bottom die block, hence no further locators are required.

Core Pins

Several alterations are to be noted in respect of these important mould members. In order to secure better retention and to obviate any tendency for the core pin to be pulled forward into mould cavity by the action of the ejection sleeves, each pin is provided with an enlarged head portion fitting into a convenient recess in bottom plate, as shown. The enlarged shank is also a very tight fit within the hole in this plate.

The drawing also shows each pin on its long, plain shank portion, reduced slightly in outside diameter for a good proportion of its length. This will make for easier sliding action within the ejector sleeve, with less risk of binding, wearing or seizing, as less surface will be in contact, and the small clearance afforded by the reduced shank portion will act as a reservoir for grease or other lubricant.

Another advantage resulting from this feature is that should the stripper bar and attached ejection sleeves become slightly warped, or guided on a non-true path from some cause, this trouble, if of small dimensions, will not be conveyed to the core pins in any harmful degree.

Bottom Plate

Finally, it will be observed that the surface of the bottom plate adjacent to the lower edge of bottom die block is cut away on certain portions, so as to leave a three-point contact only for the stripper bar. If this bar contacts full length with the bottom plate, adhering material, dirt, particles of grease or lubricant accumulations may collect behind the stripper bar, and will become trapped thereon, thus restricting its complete return. Should this occur the end of ejection sleeves would project slightly into mould cavity, which would cause a knob to be made too short on its shank portion.

By cutting away considerable amounts of the surface material on the upper side of the bottom plate, clearance space is provided for loose material and foreign objects.

Conclusion

Only a few of the many typical mould constructions have, of course, been dealt with, but it is hoped that these analyses and suggested improvements will have served to point out general lines upon which the designer, mould engineer and toolmaker maintenance man can co-operate in ensuring mould designs capable of giving a high degree of accuracy, substantial working life, smooth operation, prolonged absence of serious wear, greatly reduced maintenance service, better facilities for coping with the effects of wear, distortion and weakness, the fuller use of standard components, such as sleeves, dowels and the like.

In a final section the author hopes to have an opportunity of presenting a number of other mould designs and constructions as employed in the injection process, so as to indicate a number of commonly recurring undesirable features, which incur additional and often unnecessary maintenance attention.

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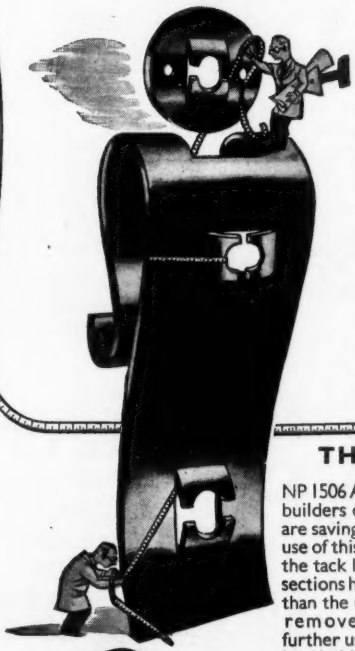

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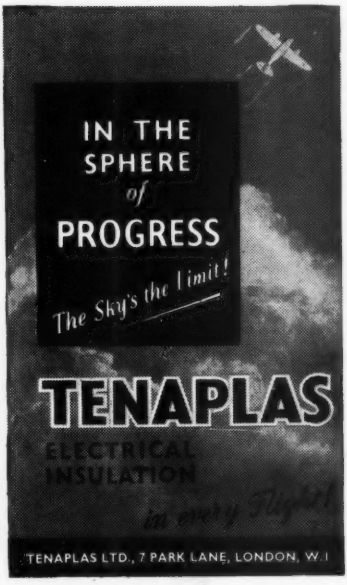

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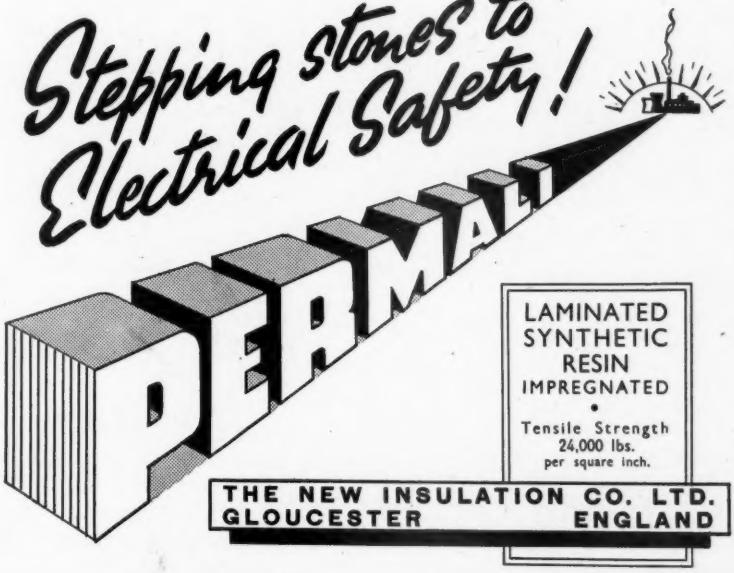

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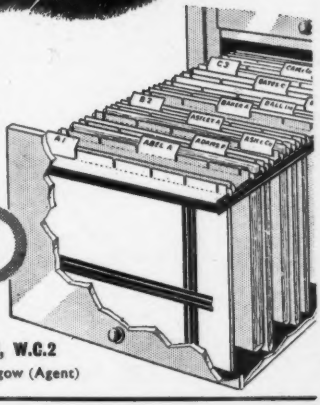

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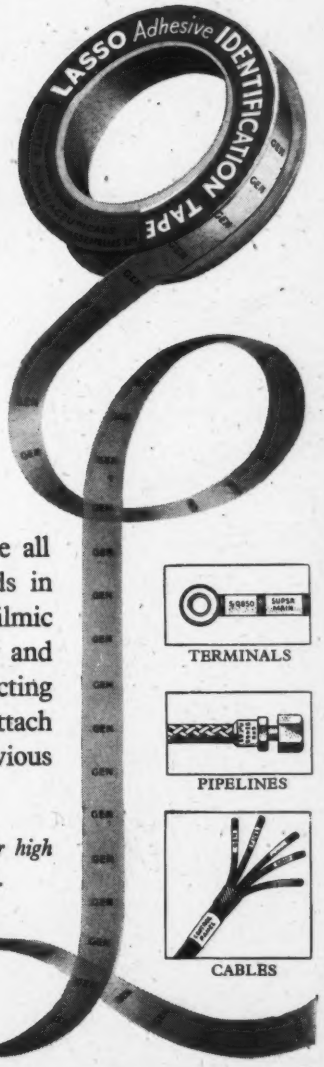

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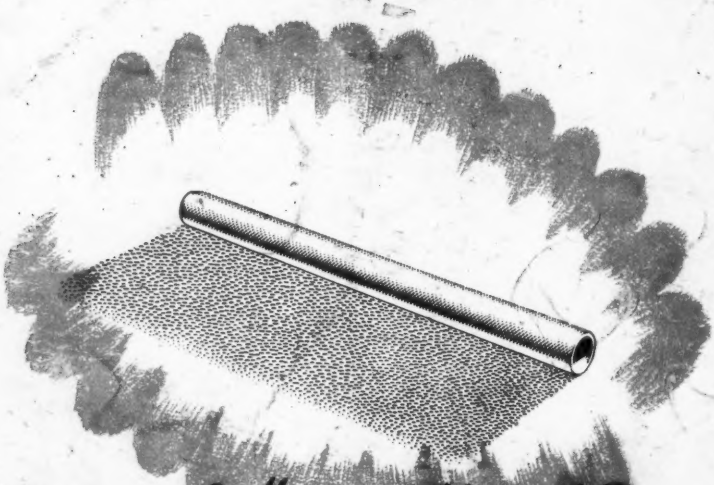

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